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SYSTEM PERFORMANCE ASSESSMENT AND CONTROL CONCEPT (SYPAC)

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October 1977

SYSTEM PERFORMANCE ASSESSMENT AND CONTROL CONCEPT (SYPAC)

Georgia Institute of Technology

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The SYPAC report is the result of nine years of research on system performance assessment and control, buttressed by field measurements, operational evaluations, and special studies. The resultant output is a System Performance Assessment and Control (SYPAC) concept suitable for implementation in the Defense Communications System (DCS).

Specific examples of the problems faced in a wide flung communication systems such as the DCS are given along with some of the procedures to identify,

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isolate, and quantize the difficulty.

The use of Automated Tech Control (ATEC) hardware is demonstrated to portray the capability offered by this automated sensing assembly. Selected printouts are provided to clarify these examples.

The rationale is given for the approach selected and the impact is presented on the operations, organization, analysis, software, hardware, and orderwire activities of the Air Force and DoD.

The SYPAC concept is a communication system control approach where the control mechanism derives its instructions from processed data based upon performance assessments:

a. Of a few selected signal and channel parameters that represent the integrated performance of a large number of devices.

b. At convenient central concentration points that also minimize maintenance and operational personnel by demanning many sites and locating most personnel at logistically and administratively convenient locations.

c. With minimum required automated assessment instrumentation.

d. Conducted in-service.

e. That are non-interfering to customers.

f. Followed by automated assessment, data reduction, analysis, and reporting through lateral and vertical orderwires.

g. Resulting in appropriate control exercised through control mechanisms and downward orderwires to impose any needed adjustments or restructuring.

The SYPAC report is written in non-scientific terms so that high level managers as well as working level programmers and staff agencies can quickly grasp the approach and intent. Thus, it can be used as a general policy guide for management and staff actions at all levels. Certain portions may be overly detailed for those people who have in-depth knowledge of the Air Force or the DCA Performance Assessment Programs, but in general, it is written for all people who operate, manage, or maintain the DCS.

PREFACE

This effort was conducted by R. L. Feik in association with Georgia Institute of Technology under the sponsorship of the Rome Air Development Center Post-Doctoral Program for the Air Force Communication Service. Mr. T. Yium of the Operations Research Analysis Office of Hq AFCS was the task project engineer and provided overall technical direction and guidance.

The RADC Post-Doctoral Program is a cooperative venture between RADC and some sixty-five universities eligible to participate in the program. Syracuse University (Department of Electrical and Computer Engineering), Purdue University (School of Electrical Engineering), Georgia Institute of Technology (School of Electrical Engineering), and State University of New York at Buffalo (Department of Electrical Engineering) act as prime contractor schools with other schools participating via sub-contracts with the prime schools. The U.S. Air Force Academy (Department of Electrical Engineering), Air Force Institute of Technology (Department of Electrical Engineering), and the Naval Post Graduate School (Department of Electrical Engineering) also participate in the program.

The Post-Doctoral Program provides an opportunity for faculty at participating universities to spend up to one year full time on exploratory development and problem-solving efforts with the post-doctorals splitting their time between the customer location and their educational institutions. The program is totally customer-funded with current projects being undertaken for Rome Air Development Center (RADC), Space and Missile Systems Organization (SAMSO), Aeronautical Systems Division (ASD), Electronic Systems Division (ESD), Air Force Avionics Laboratory (AFAL), Foreign Technology Division (FTD), Air Force Weapons Laboratory (AFWL), Armament Development and Test Center (ADTC), Air Force Communications Service (AFCS), Aerospace Defense Command (ADC), Hq USAF, Defense Communications Agency (DCA), Navy, Army, Aerospace Medical Division (AMD), and Federal Aviation Administration (FAA).

Further information about the RADC Post-Doctoral Program can be obtained from Jacob Scherer, RADC, telephone AV 587-2543, Commercial (315) 330-2543.

The author wishes to thank the many officers, airmen, and civilians in AFCS who have assisted in performing the assessments and network evaluations needed to develop and prove the System Performance Assessment and Control concept. Special recognition must go to Capt. Jacque Lemelin and CMSgt Russell Miller for their special system testing with the ATEC hardware at Croughton, England.

The author wishes to thank Mr. T. Yium, Hq AFCS, for his in depth and continuing support and suggestions all through this effort.

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<u>Illustrations & Tables</u>

PREFACE

The author recognizes that the people for whom SYPAC was written are busy, therefore, the following comments may be of interest to readers.

1. The thoughts in the Preface on System Control, Management, and Performance Margin are prerequisites to the reading of any section.
2. The sub-section in Chapter V on Integrated System Assessment is in one short portion the sum total of the SYPAC concept. If the technical approach is not clear, then more reading in the earlier portions will be required.
3. Chapter VI, SYPAC Impact, is really a narrative introduction and discussion to an operational and a cost effectiveness study.
4. Chapter VIII, Digital Considerations, discusses the application of the SYPAC concept during the transition to a digital DCS.
5. Chapter IX, ATEC Proof of the SYPAC Concept, discusses some of the work conducted using the ATEC hardware to explore, develop, and finally prove the basic SYPAC theses.
6. The last chapter, SYPAC Implementation, is three pages long, but if ATEC/SYPAC implementation is not in accord with the stated simple but important sequencing, the cost effectiveness is assured of being less than optimum, and the actual cost will be much higher than necessary.

System Control

All systems are composed of subsystems and component elements with many variables and adjustments. If all parts of the system can operate in but one way, and the interaction of each part with all interfacing parts is possible in but one prescribed manner, then there can be but one operating mode. Control of such a system is simple and need be little more than an on/off switch. However, most real life systems have variables, and the desired output must change from time to time. The control of these variable type systems is more involved. In a communications network, there are many variables. The communication equipment hardware is a variable and is a function of the original design, the production quality control, the installation suitability, the maintenance effectiveness, the operational conditions, and the type of service required. The hardware is intimately interfaced many places with the human - obviously a component of high variability. A customer of the communication system has certain rights; they are, however, not inalienable. Hardware problems or any human involved as a maintainer or operator can degrade or disrupt a part or much of the total system, and the customers themselves can disturb their own service or that of others. Thus, control is required to correct any disturbances and restore effectiveness and stability to the system.

System Control, then is defined as the continuing adjustment of all needed elements of the total system to assure proper operation of not only all the hardware and software elements, but of the composite total system; while constraining users the minimum amount necessary to protect the rights of all customers. A prime function of Control is to absolutely assure that

higher priority users can, at necessary times, communicate as required, but at the minimum expense required to lower priority users.

Certainly, no control should be exercised when all is well, but equally obviously, control must be applied when changes are needed. Therefore, before any control is exercised to optimize performance, the status of the system to be controlled must be known. The knowledge of the system status presumes the ability to measure and quantify the key parameters descriptive of system operation. This in turn infers that all of the good and sufficient parameters descriptive of system performance are known, and such is certainly not the case. As a result, the final DCS control structure cannot be implemented now. AFCS has worked for the last eight years on a broad spectrum of activity deriving, refining, and field proof testing parameters that describe system status.

The performance assessment parameters thus far selected were intended from the start to form real time system performance parameters required for total system control. This SYPAC report is a discussion of much of that work and describes a SYstem Performance Assessment and Control concept based upon these proven performance assessment results, and contains a logical extrapolated approach to Control functions.

There is a concomitant requirement that plays a very strong role in the formulation of the SYPAC concept. People are frequently fallible, and they integrate poorly with high speed automated mechanisms. Thus, the SYPAC concept minimizes the human serial participation. This concomitantly reduces the number of people required to operate and maintain the system and provides major associated cost savings.

Performance Margin

Performance margin is the term used throughout this report to denote a concept relatively new to the military communicator. An understanding of the performance margin idea is necessary. A homey example may be useful to illustrate the performance margin notion. Suppose a new car can deliver 35 miles per gallon, when all adjustments are appropriate. Later, after service use, the ignition points are slightly pitted, the compresssion in the cylinders has fallen some, the carburetor is slightly maladjusted, and the ignition timing has changed. The gas mileage now has dropped to 30 mpg. Clearly, the performance is not peaked, but the car still will start, run acceptably, and meets the needs of the user. More car usage will result in further degradations and the mileage may drop to perhaps 25 mpg, yet even then the car may start and run - if the weather is mild. The performance capability has truly degraded, but may not be precisely visible unless miles-per-gallon records are reviewed. If the weather, however, turns cold, the car may not start even with a good battery. At the no-start point, the fact that maintenance is needed is obvious. Most people will blame the weather, but the basic problem is clearly lack of maintenance. The operational need cannot be met, so the performance margin is zero. Had the driver of this example car made assessments, he could have detected the performance degradation as soon as the mileage dropped below 33 mpg, for example. In this case, the performance margin is 10 (35-25 mpg).

Let's assume that the car owner takes his car to a garage, and upon completion of the repairs finds his mileage is 32 mpg. He would know absolutely that all repairs had not been made, no matter what maintainer protestation he may be given. A repair job that restores 34.5 mpg is a good one. The owner with good basic initial performance data and good records can know exactly his performance degradation. This will permit him to manage his car, but more importantly, he can assure that his auto is immune to hazards of weather extremes.

This idea of performance margin applied to a radio link is equally easy to grasp. When a radio link is designed 40 db - 10,000 times more signal is provided to the receiver than the minimum actually required. This excess signal is intended to permit acceptable operations -- even when heavy rain storms pass through the radio path, when temperature inversions cause the signal beam to wander off axis, and when multipath effects degrade the signals. Each of these effects can induce signal losses of 30 db or more.

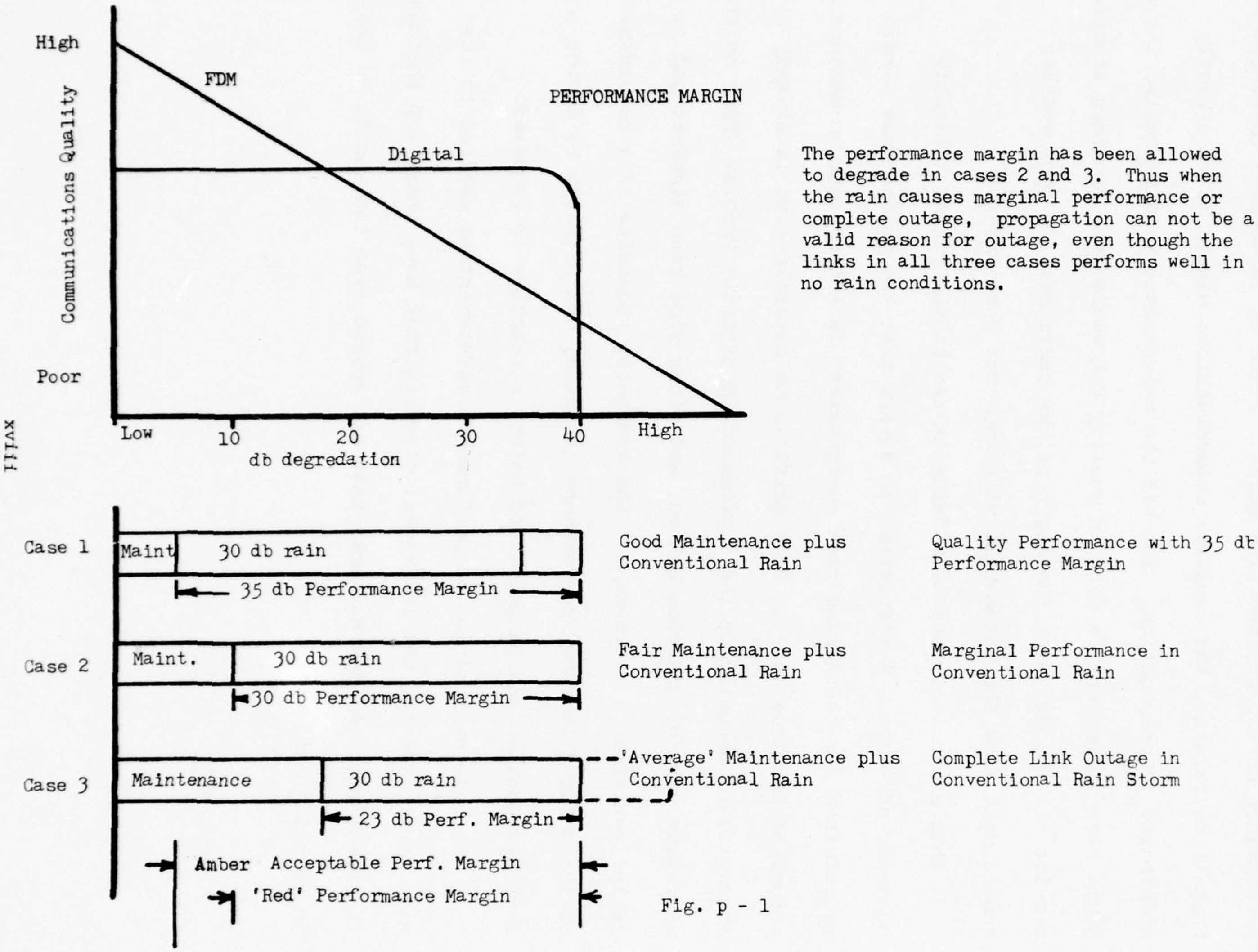
The performance margin must be maintained during relatively normal periods between these primarily weather induced phenomena. Maintenance personnel frequently permit the adjustments to drift, the receiver to desensitize, the transmitter to lose power output, and the electronic componentry to get noisy. In fact, the users still get acceptable service during good weather even though the radio equipment is badly degraded, 17 db is about average (50 times too noisy.). This poor maintenance does not really cause too much operational trouble until one of the original

reasons for the provision of the performance margin occurs. When a 30 db rain storm arrives, the 40 db performance margin is inadequate. The 17 db equipment degradation plus the 30 db storm deterioration exceeds the performance margin and the link quits. Since it is obvious to everyone that it is raining, the complete communications outage is incorrectly attributed to propagation. Yet had the maintenance been adequate, the rain would have caused only a drop in quality but would have provided acceptable service all through even the depth of the storm much as cold weather should only slow the automobile starting, not preclude it.

This above logic has been demonstrated in the field, literally hundreds of times. A requisite, to assure that the performance margin is retained for use during real emergencies, is a technique to measure the actual performance level. Such performance determination is already being accomplished manually by the Performance Monitoring Program (PMP) on the microwave, tropo, undersea cables, and other wide band elements and is called performance assessment. The remaining requisite is a determination of the basic "like new" performance standard, and criteria to decide how much degradation can be permitted before correction is required.

The full explanation of performance assessment as applied to the wide band elements, the individual circuits that wend their way through the structure, and the networks that are spread over the world, is covered in detail in this study.

PERFORMANCE MARGIN



The performance margin has been allowed to degrade in cases 2 and 3. Thus when the rain causes marginal performance or complete outage, propagation can not be a valid reason for outage, even though the links in all three cases performs well in no rain conditions.

Fig. p - 1

Management

The term management means many things. Most definitions however presume that the manager possesses an understanding of the mechanism to be managed. In addition, there can be no effective management without near real time reporting of the information disclosing the actual system status. There are several schools of management. The one most widely exercised by military managers is "Management by Exception." "Management by Exception" perhaps even more than other approaches, however, requires not only sensing those critical parameters that indicate when the system is not operating correctly, but it also presupposes an unfailing reporting structure, with appropriate processing of reported data to each level where management and corrective actions are required -- in other words, notifying management that an exception exists.

SYPAC has as its goal the full management of the communication system, including the system status and control of all critical system elements. The SYPAC goals can be summarized as providing management answers to the following questions:

Is there a problem?

Where is the problem?

Is there an adverse trend within the system?

Then, based upon this information permit the manager to:

Control correction of the identified problems before failure of any operational service.

Restructure the system to meet changing operational requirements.

Evaluate the effectiveness of hardware and operation and maintenance throughout the system.

These very simple goals now are placed in a true systems context. Thus, for example "Is there a problem?" means is the 'performance margin' degraded such that multipath, rain, heavy fog, or temperature inversions would produce unacceptable communication service. "Is there a problem?" can no longer be an administrative query whether there are any customer complaints. A customer complaint means that the system has already exceeded the entire performance margin, and has failed.

This author has found contrary to common opinion that the most important single matter in the system control spectrum of issues is establishing beyond a doubt that "There is a problem"! Once this fact is accepted, all personnel are quite willing to attack the fault isolation and problem correction. The generally slow and marginal DCS maintenance and operational corrective activities are a direct result of many people failing to see that a problem exists - or that the problem as presented to them is unimportant as they see it. Therefore they recognize no 'real' problem, and fail to act.

I. INTRODUCTION

The Air Force Communications Service is assigned the responsibility to operate and maintain the majority of the communications within the Air Force, and is designated the responsible Operations and Maintenance (O&M) Agency for more than half of the Defense Communications System (DCS).

The Command has been struggling with the problems of managing this wide-flung communication structure, including efforts to make all of the hardware play together properly. As part of this effort the Command has been trying to restructure and decentralize those functions best accomplished at lower organizational levels, and to centralize only those functions done best at some higher headquarters. Many lessons have been learned. There are a number of management actions now underway to improve management of the communication structure; but there is no viable, published system management concept yet available to guide these efforts.

The following SYPAC study was conducted to devise such a generalized approach and to publish a viable, integrated system management concept.

The inputs to this study were highly varied and included both theoretical and practical considerations. The Air Force has implemented and has in daily use a number of mission management assessment programs and these have provided deep insight and have exposed some ideas that were marginal or non-cost effective. The Automated Tech Control (ATEC) program has entered its test phase and has been extraordinarily productive in demonstrating many of the performance assessment capabilities needed as the inputs for system management and control. Discussions were held with many people at all levels to elucidate vital management and technical factors.

Everyone agreed that no system solution could exist that independently examined organizational, technical, and management matters. This study has kept all of these considerations in mind.

The "Systems Performance Assessment and Control" concept describes a viable, efficient, and cost effective approach suitable for the Air Force and DOD implementation in the DCS.

A. Problem

The following paragraph is a quote from the author's original Semi-Automated Technical Control (SATEC) report published in September 1967. The problem as summarized has not changed in principle. The absolute status of any particular element may have progressed; the understanding of system issues is surely greater; and the number of individuals working on system control is larger, but the basic problems still remain.

> " ... system technical managers have not been succsssful in providing rapid, precise, and documented quality control, analysis, altroute, restoral and other functions demanded by our communications systems requirements. ... The report further shows that management and technical requirements to create the desirable concept of operations for technical control must concomitantly address and reconfigure existing organizational structures, programming, specifications, operations, maintenance and logistics concepts and reporting and analysis procedures and requirements."

Of particular note is that in 1967 the SATEC report emphasized the thought that the system control concept "must concomitantly address and reconfigure existing organizational structures, ... operations, maintenance and logistics concepts, and reporting and analysis procedures."

The problem, as stated in 1967, clearly addressed the total system and these issues still remain the problem to be solved.

B. Background

The communications complex assigned to AFCS is a heterogeneous group of equipment including both military and commercial hardware. The complex was built over a 20-year period with little overt system engineering. In the 1960's there was a rapid expansion of many of the facilities around the world. This produced increased channel capability in many areas, but resulted in even less total system integration. Recognition of this fact lead to the establishment of the Defense Communications Agency (DCA).

Initially, the communication plant adequately served the undemanding teletype and voice services for which it was intended. However, the rapid growth in record data demands, automation, world-wide disposed networks, and more severe operational requirements soon exceeded the capabilities of the Defense Communication System. The problem of providing modern communication performance with an old plant in place was recognized. The earliest efforts to meet increasing needs for "data record traffic" of the Air Force started with the installation of minimal test equipment to improve the tech controls. Simple monitors and alarms in tropo, microwave and cable segments were developed and installed. The implementation of the common user switch networks, with their capability to provide fast switching and alternate routing interconnections world-wide, have created expanded communication capabilities, improved customer service, but have added even greater technical complexity to the unsolved system management problems.

The services have taken only limited test and overbuild actions in reaction to identified customer "network" problems. These actions were predominantly directed toward improving the operational performance of a

particular piece of communication hardware, suspected of causing problems - generally customer complaints. With the inception of the DCA, they lead committees, panels, and working groups implemented to address specific problems areas and to attack particularly perplexing issues. The actions taken by these groups have ameliorated specific difficulties, but have not eliminated those total system related problems which were and still remain the major operational and technical DCS impairment.

In the last few years, AFCS has learned how to assess the performance of many portions of the system, learned to analyze the assessment data, and to convert much of the analyzed data to meaningful management actions. Unfortunately, most of these actions are manual, slow, and expensive. As a result, many of the productive analyses and corrective actions have not been accomplished. The present management control is focused by necessity in the tech control facility, whose present configuration and methods are outdated and certainly have little relationship to modern system performance assessment, network/system management or customer service evaluation. These tech controls in themselves contribute to the system substandard operation.

During the last nine years, AFCS has conducted a number of highly sophisticated and well-instrumented field evaluations and studies, addressing specific goals, but always with an eye toward integrating the results in a general approach to system management and control. All of these programs were implemented in a manner quite different from previous approaches. These efforts were headed by engineers with special non-device oriented broad system training, hand selected technicians with a broad range of hardware experience, especially selected test equipment, carefully

prescribed test procedures, and, of major importance, with data analysis required to identify: design, engineering, operating, maintaining and supervision problems. Some of these programs include: Scope Creek (Now the DCA Technical Evaluation Program);Link Assessment Program (Now the DCA Performance Evaluation Program); Mistic Star and Aeronautical Station Assessment Program; Joint Autosevocom Assessment Program; and the Weather Facsimile Network Assessment Program. The above characterization and assessment programs have all provided management with information weeks after the measurements, and have been fairly labor intensive. Nevertheless, they have provided meaningful data never before available, at a labor cost that was tenable, and with sufficient insight to permit intelligent management decisions, and with considerable demonstrable results to help justify the resource cost. The AFCS 'Blue Book' correlating TEP and PMP wide band structure performance results, and high lighting needed corrective action is but one example.

During the conduct of the Scope Creek characterization effort, it was observed that there was a relationship between a few selected, non black box performance parameters, and the quality of service provided to the subscribers. Further, it was noted that these parameters, once degraded, tended to continue to decay. Although specific relationships at that time were not well understood, Scope Creek personnel became proficient in anticipating major link problems - a rudimentary and imprecise, but nevertheless real, failure prediction capability.

Some of these informative measurements had been available prior to the Scope Creek effort, but the necessary analysis capability was not present in the field. Skilled maintenance personnel were capable of analyzing their own measurement data, but only as it related to the specific hardware then being measured. Scope Creek personnel examined their data in a broader context, as it related to the total link. This broader consideration was the beginning of true systems analysis.

The ability to anticipate failures was a new one in the DCS. Until Scope Creek, the prevailing concept for management had been based upon rapid restoral after a failure had occurred. This "fix after failure" approach was an easy and comfortable one because it required no work on the part of operations or maintenance personnel until something failed, and it required little in technical competence by supervisors. Unless a customer complained that his service was unsatisfactory, all personnel assumed that no failures existed. Before Scope Creek no practical alternate concept existed. Little thought was given to devise better ways to approach communications management. <u>Further, the Bell System uses predominately the customer initiated failure notification approach. The normal user of the telephone system can expect little or no attention unless he complains.</u> The military approach was based upon the commercial "fix after failure and customer complaint" policy. Bell provides the commercial high priority users, such as television networks, manual monitoring in Bell tech controls with alternate routes established quickly. This latter alternate route concept cannot, in general, be applied by the military. Many of the most important command and control routes have no possible alternate routing. Even

where feasible, most alt-routes pass through such a conglomerate of commercial and military facilities that coordination alone precludes anything rapid. Thus, the military must solve their own special system control problem in a different manner. The DOD must accommodate to all the unique operational features and capabilities not faced in the commercial world, and for which there is no commercial solution "off the shelf."

The Air Force Scope Creek effort opened the door on not only a viable military approach, but it also came at a time when the old "fix after failure" concept was proving poor even for relatively forgiving teletype traffic, and was incapable of satisfying even the medium speed services then entering into operational use. The "fix after failure" concept is only now being recognized as completely unsuitable by most key personnel.

There were several long range benefits from Scope Creek and the other assessment programs:

a. There were immediate field hardware improvement gains.

b. There were measurement and management concepts and techniques created and implemented.

c. In retrospect, the prime benefit was quite clearly related to surfacing and understanding the technical system issues.

Scope Creek personnel had the chance to examine backbone and network difficulties in depth, the opportunity to analyze the performance assessment results, and the time in the field to consider and evaluate the broad principles of assessment and control for the total worldwide communication system.

The SYPAC system control concept is based upon the principles derived during all of the performance assessment programs.

C. Present Status

Any analysis clearly demonstrates what is really self-evident, that existing tech controls, operating in accordance with present philosophies and hardware, are not capable of solving system problems. The system control problem intractability becomes even more obvious when it is recognized that links of several commercial companies are normally encompassed in any significant network, so both management and technical matters are fractionated between the commercial and military organizations. This reduces even further the likelihood of success. The operational performance of these worldwide networks is the integrated sum of all hardware and personnel induced degradations which cumulatively distort, mutilate, or destroy customer services, and provide subscriber satisfaction far below that achievable if all of the structure were up to the actual hardware electrical capability, with all interfaces and operational adjustments appropriate.

Today tech controls make manual measurements of signal level on an in-service bridging non-interfering basis. The measurements produce some operational gains, but are not nearly adequate. More informative measurements including noise level, distortion, etc., are possible, but they require removal of the circuit from operational use. The fact that most networks are operating much of the time makes periodic removal from service for testing operationally unacceptable and further impedes and often prevents

even the attempts to provide higher quality service. There are few effective network assessment procedures, and no effective customer service oriented evaluation concepts in use in the DCS.

Thus, it is clear that, without these performance measurements, the condition and status of the entire communications structure is undefined. There can be no effective service optimization, or structuring to meet operational needs even in a stable environment, and obviously no control capability to restructure and optimize rapidly in an emergency.

Adequate system assessment, upon which to base system control, clearly is the key missing element in the worldwide operation of AFCS communications facilities. However, it does not follow that just any assessment or corrective action, procedural adjustment, or equipment change will be effective, even though it may be acceptable from a cost, size, or function viewpoint. All changes must be viewed from a total system context, and interrelated to every other facet of AFCS activity including organization, reporting, personnel, logistics, maintenance, etc. For example, system control cannot be optimized only for communications system hardware control, for then the operational and management control could suffer. Likewise, overconcentration on operational control might severely limit network or hardware fault isolation or maintenance actions. Thus, a considered approach, balanced in all aspects, must be followed. Figure 1-1 graphically displays the major complex interface areas that must be examined in detail to assure full compatibility. This SYPAC concept addresses all factors in consonance.

SYSTEM CONTROL INTERFACES

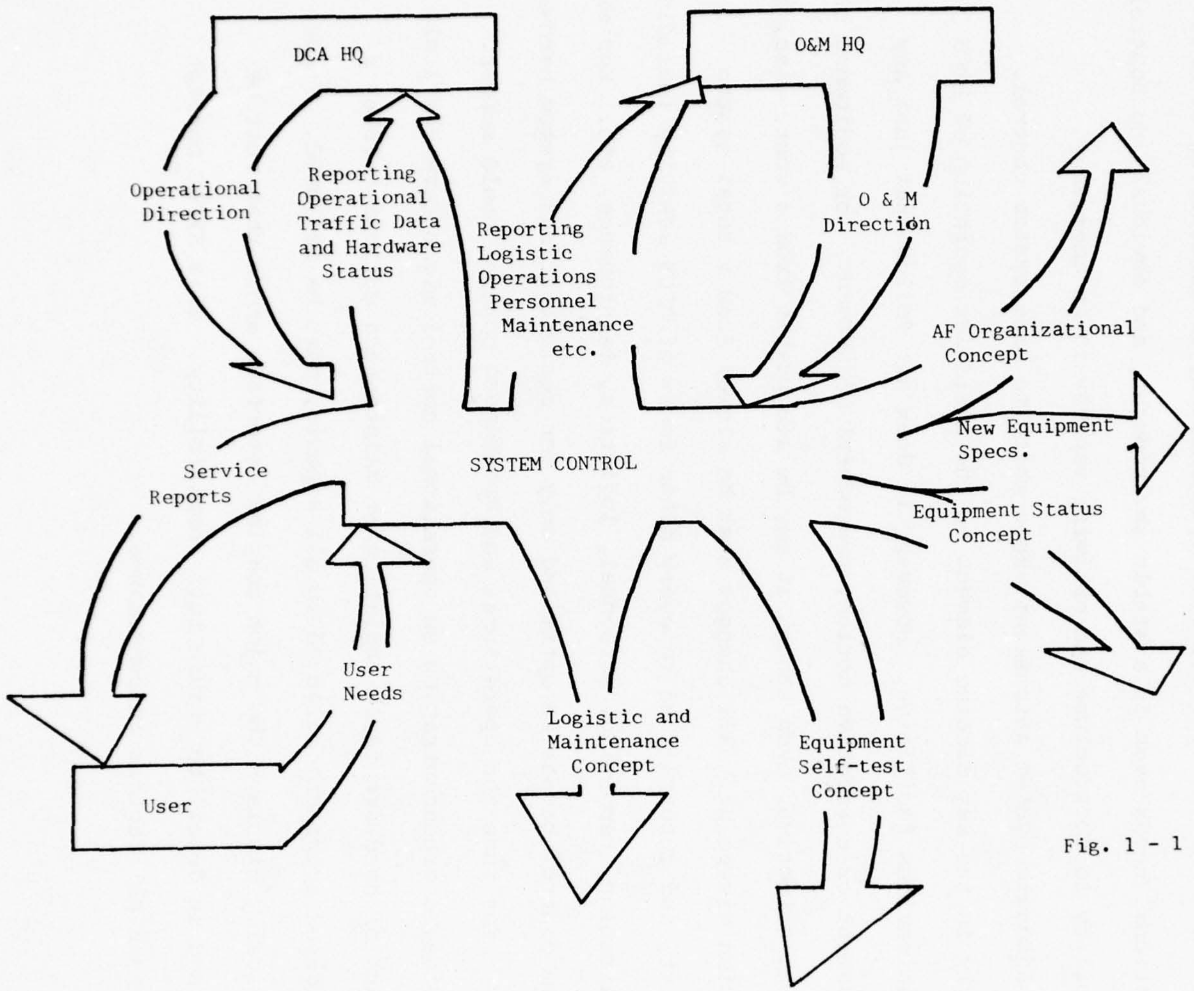


Fig. 1 - 1

This Introduction describes the conditions of much of the DCS as it now exists. Yet in fairness to many of the Army, Navy, and Air Force tech controls, these conditions have improved -- an improvement brought about by the incorporation of the Performance Monitoring Program (PMP) replete with new test instruments, some analysis, some reporting, and some management feedback and direction to the reporting activities. This effort, while not equally effective at all stations, and widely variable in its results among the services, achieved approximately 10 db improvement in voice channel performance, as measured across much of Europe although this gain can quickly be lost when management lapses. (See Fig. 4-8.) (This gain was achieved before overbuilds were made.) It is important to note that the PMP effort is a manually implemented incomplete version of the ATEC (Automated Tech Control) approach. Much of the SYPAC concept, including the approach, the technique, the analysis, the cross tell laterally among the concerned tech controls, and the management concepts have already been tested and and validated. Thus ATEC is in theory and also in practice, the first partial implementation of SYPAC. The salient point is that the basic SYPAC concept has already provided a 10 db gain European wide, and nearly that gain in the Pacific, and some networks are now serving considerably better.

Even with these gains, so much remains to be done that the statements concerning the present degraded system status are still generically accurate.

II. PREVIOUS FAULTY SYSTEM CONTROL CONCEPT

It is interesting and informative to examine the communications management concept in existence in 1966. The management concept was based upon data derived from a manual periodic quality control (QC) go no-go type measurements on all circuits in the wide band links, conducted monthly, quarterly, or on some other rather long term period. It was presumed that "someone" would continue to work on the no-go problems. Hidden within these premises was the supposition that all personnel responsible at all levels within the organization would be capable and motivated to perform in-depth analysis of the data and identify problems or questions. Everyone "hoped" that the QC data would provide sufficient information and somehow generate concomitant corrective action to keep communications flowing acceptable. None of these suppositions was realistic.

The policy to QC all wideband circuits probably was a holdover from the early days when a limited number of land lines and only a few high frequency (HF) radio channels were involved and where the circuit was from user location to user location. HF circuits ran among a very limited number of stations. The amount of measurement information that had to be interchanged among stations when troubleshooting was quite small and the number of stations involved was never very large. Most of the time only military circuits were concerned, and multiple alternative paths were nearly nonexistent. However in 1966 even a medium size tech control had several hundred circuits, and the large ones had thousands with varying signal and circuit characteristics. Further these circuits were now QC'ed tech control to tech control so constituted but a small portion of the path of interest.

The customer interconnections were either analog voice or slow speed teletype. Since the voice and teletype terminals themselves were easy to keep operational by equipment substitution, the bulk of the service problems were correctly attributed to the interconnecting circuits. Thus, the customer normally and correctly blamed the communicator for most service degradation and disruptions. The communicator had no network data, so could only refer to his QC sheet and state that the problem was not at his end, so it must be at some remote point. This "passing the buck" became a well-known ploy and caused the military to look with skepticism at the communicator.

By the late 1960's, however, things had grown even more complex. Circuits ran worldwide, with some appearing in more than one hundred sites. Most tech controls had many circuits appearing on the patch panels. The circuits ran through US military and both US and foreign commercial lines, and some passed through allied military structures.

Whether the original HF QC data was gathered and effectively analyzed to give good service in the old days is not known. However, even assuming that all the QC tests were accomplished accurately and correctly in the late 1960's, there still could not have been adequate management of the communications system. The QC "OK" and "Not OK" data is not sufficient. A circuit may be adequate for voice, marginal for teletype, and unusable for high speed data. Obviously, many factors are directly involved, including both people and hardware, upon the distance traveled prior to entry into the measuring tech control, distance yet to go in the system, and sensitivity of the particular signal to disturbance -- all must be considered in any

viable management concept, and this creates a formidable analysis problem.

Thus in 1968, the communicator was faced with a communication structure that gave increasingly poorer performance with each increase in speed, and demand for better reliability, and the users were unhappy. It was a natural reaction for the field personnel to request some sort of an automatic QC device. Unfortunately, in the 1960's, no meaningful system analysis had been performed and the resultant development of an automatic quality measuring mechanism failed to even address the basic system problems of degraded hardware operation, lack of system performance visibility, absence of fault isolation capability, and non-existent analysis competence to correlate observed customer service with the few channel parameters measured.

The hardware that was developed was predicated upon an assumption that *was completely wrong,* and so basic to the approach that no practical operational returns resulted from its installation. The faulty premise was that all circuits in a tech control had to be sampled in a short time. This meant that each channel was sampled very quickly and nothing much more than a simple signal level measurement was possible. The ensuing analysis was automated and gave an indication of a signal present, not present, or questionable. Reports were automatically prepared for processing to higher HQs - the function that is always easy to do with a computer. The field troops liked the device because it replaced some of the routine daily QC tests and prepared some end of shift reports. Unfortunately, there was no perceptible increase in system performance, and no improvement in customer service. Although the contractor extolled the merits of his box, the

evaluation, done by an impartial agency called in by the developing service, stated that the benefits derived consisted mainly of alerting the tech controller of a signal failure about 10 minutes before arrival of a complaint call from the customer who had lost service. The costly rapid scan equipment permitted restoral action to start 10 minutes sooner!

It is a fact that the sources of trouble that degrade a communication structure nearly always - with a very very few exceptions - develop slowly over periods of days and months. The assessment problem is one of making a measurement of sufficient breadth and accuracy to correctly identify and bound a problem, so that it can be fixed. Whether the difficulty is located now or one hour from now is of little operational impact. Thus the problem is one of making meaningful performance assessment measurements, calculating trends, and analyzing them in sufficient depth to identify, isolate, and correct the problems while the service is still acceptable rather than detecting a failure and then trying to react quickly. If the corrective action is just reasonably responsive very few users will ever again lose service. Restoral action will rarely be needed since problems are found and corrected prior to failure.

Failure of the QC concept whether manual or automated could have been anticipated. The dismal performance and poor reputation of the QC management concept is but a small portion of the logic why the SYPAC concept will not mention nor use the term QC. Performance assessment is an entirely new approach and is not a spruced-up QC effort.

Circuit assessment capability is retained in the SYPAC concept, but not in the QC context, not accomplished the same way, and not for the same purpose.

III. SYPAC CONCEPT OF OPERATION

A. Control System Criteria

It is obvious that any involved structure must be at least qualitatively understood before the first steps of control can be considered. In the case of the DCS communication system, there are four major technical prerequisite criteria.

1. Assessment and Control of each Sub-Element

Since the DCS communication structure is so involved that is cannot be controlled as a single entity, sub-divisions must be made. There are many ways in which a large and worldwide structure can be sub-divided. There is no absolute method to pre-assure selection of appropriate sub-groupings. If the wrong subdivisions are selected, the cumulative reassembly later into larger elements will lead to difficult, intractable, inconclusive, or completely impossible assessment or control difficulties. The economists of the world have never solved their sub-element breakout problem and, consequently, analysis and attempts to control any large economy leads to inappropriate or disastrous results. The dissection decisions are difficult since all of the resulting parts have to be amenable to performance assessment and capable of accepting control. The sub-divisions have to be suitable to further dissection with the lowest element being a single electronic box. The assessment and control criteria must hold for all sub-divisions.

For example, visualize a large group of equipment system engineered to perform some function. If the assembly is designed as a system, each box

will have had designed-in methods to determine its own performance and also adjustments to control or optimize its functions in service. As more boxes are interconnected in their normal operational arrangement, assessment and control features will have been provided. The assessment and control criteria holds through all the ever-increasing size of the assemblies until the full system is complete. The ability to assess the performance and to control the operation of the full system, of course, is the result.

Every major system must meet this assessment and control criteria, or else periodically, when operations deviate from the desired or fail entirely, the system or some portion must be removed from service, so that the maintenance men can disassemble the hardware and by use of test equipment move step-by-step, box by box to isolate the problem.

What is now the DCS was originally assembled without a system engineer, so the above necessary assessment and control criteria was not met, although some devices have partial assessment capability. Consequently, the test equipment, out-of-service control approach is the only possible result. The SYPAC goal is to solve the assessment and control problem, after the assembly and fielding of the system. A difficult issue was to find suitable subdivisions capable of meeting assessment and control criteria. Further, even when the sub-elements can be combined, analyzed, and controlled theoretically at each of the levels or higher order combinations, it is also required that each level of assembly have a realizable practical control element embodiment at a cost that is reasonable.

2. Good and Sufficient Performance Parameters

It is self-evident that no system can be controlled unless "good and sufficient" performance parameters have been identified. No industrial plant can function without many sensors to provide data for manual or computer manipulation for control of the process. These parameters must be unambiguous, and must assess all the critical processes of the plant. If all the readings sensed are acceptable, there must be a high probability that the whole process status is also acceptable. If this is not so, either some parameter is improperly sensed, or worse, some key parameter, or combination of parameters necessary for control of the process has been ignored. The dissection of a worldwide communication structure into sub-elements, and the derivation of meaningful performance parameters has not been easy nor fast, but has been an iterative learning process based upon the Technical Evaluation Program (TEP) and Performance Monitoring Program (PMP) efforts. Inability to describe meaningful, measurable parameters forced re-examination of some of the original sub-element structures. Inability to further divide while still sensing and controlling some sub-structures has required rethinking the basic subdivisions. No insoluble dilemmas on the subdivisions now remain. AFCS has completed sufficient iterations to have arrived at a practical, effective, and sound position. As this concept is implemented, some optimization or tradeoffs undoubtedly still will be made, but the described basic concept, subdivisions and the several classes of measured parameters are both practically and theoretically sound, and form the backbone of the SYPAC concept.

3. In-Service Sensing of Parameters

The parameters that describe the performance of the system obviously must be assessed during actual system operation. Further, a measurement that disturbs the operation will give a result not indicative of the true value. This principle of careful sensing is a well known scientific doctrine.

The DCS communication system is a dynamic entity, one where the inputs and outputs vary widely with time, where the utilization at a particular time is not possible to predict, and where the important and critical system usages are during military or natural crisis where the customer loading of the DCS is maximum. This is quite different from the commercial world. The Bell System clogs under many classes of holiday usage. Bell expects this, and customers acquiesce to a structure that does not function well under high stress. The military however must sense the meaningful parameters and take necessary actions while the system is in maximum use. The concept of removing a portion of the system for test to make the analysis easier is not realistic. Removal of portions of the totality imposes changed stresses on the remaining structure, and thus, changes the operating conditions. But, of most importance, the system sensing, assessment, and control is of maximum importance during emergencies. Control is most needed then to assure command and control communications survival. Any sensing that withdraws this needed capability during the stressful conditions, or fails to be real time, is unacceptable. Thus the system sensing and resultant control must be effective while all system elements are in active stressed usage.

4. Parameter Suitability for Reporting and Control

The last criterion to be met is that processing of the "good and sufficient" performance parameters must be suitable for two purposes:

a) the control of the system.

b) processing for the preparation of reports of the myriad and voluminous type seemingly indivisible from any military or government activity.

SYPAC will meet all present reporting criteria and any new needs until such time as management formulates a streamlined and effective reporting approach. The new reporting mechanism can be much more informative, provided in near real time, and also considerably reduced in size and scope. The DCS has had neither the inputs needed for system control nor the capability to accept control even if it were attempted. Thus the first step toward SYPAC must be performance assessment and data analysis to form the heart of total system control. ATEC is the first step toward this heart.

The analysis outputs to management must be adequate for resource management, customer service assurance. and for inputs needed to future system planning.

B. Control System Criteria Embodiment

1. Backbone Structure

One of the major system subdivision for system control was recognized in 1966 and was described in conceptual form in 1967 in the publication titled "Semi-Automated Technical Control (SATEC) 5-ORR-67" by the author. It remained until 1968, however, before the concept could be demonstrated during the Scope Creek program. (DCA TEP)

Some may recall that one of the original 1968 DCA measurement concepts in 1968 had envisaged measuring the radio and the propagation path only. AFCS had already recognized that a radio and path characterization alone would be incomplete since the radio equipment covered but a portion of the hardware that could cause trouble. No control concept could view only the radio equipment and assure valid operational service-related conclusions. Scope Creek was implemented from the beginning in 1967 to include the measurement of the multiplex hardware, interface devices, cables, patch panels and including everything necessary to assess the voice channel from audio at one tech control to audio at the next tech control. The presumption that the radio and the path were the limiting service performance factors was wide spread, but measurements have proved this theoretical fact to be predominantly fiction. In real life, propagation is but one limiting element. The first few links and most tests in subsequent evaluations proved that the multiplex, radio modulator/demodulator and peripheral devices were also major degraded elements. All link elements clearly need assessment and control.

The Scope Creek measurement technique was structured to measure a box, then several interconnected boxes. The assemblies were sequentially expanded to include larger sub-elements such as a radio transmitter, radio receiver, the wave guide and antenna portions. The channel/circuit equipment was separately characterized at each end of the link. Next there were two large scale integrated measurements:

a) the radio equipment and the path elements using the widely recognized Noise Power Ratio (NPR) test.

b) the radio and propagation portion plus the multiplex and all other related hardware required to provide the voice channels from audio to the base band, over the radio equipment, and the similar hardware at the other end to return the receive signal to audio again.

The audio, through the link to audio test gave the total accumulated performance of the entire path. It is mathematically easy to calculate what this end-to-end measurement result should be. Thus, the end-to-end audio test both checked the link performance against the calculated value, and also gave the actual performance value. This measured channel data is plotted versus time for trend information for control purposes.

It also proved practical and operationally easy to similarly measure a long path having several radio hops in series. The validity of the concept was proved when correlation of all of the box measurements of one link could be summed to equal the link measurement and also that boxes in several serial links could also be correlated with the end-to-end measurement over the long multihop path. Theory had predicted this result, and no practical impediments preclude field application, presently implemented as the PMP.

Since the correlation of box measurements to the end-to-end link result is based in simple math, the result can be shown to be reciprocal. The box measurements add to the total link measurement and if the link measured total changes, the source of the change can be found in one of the boxes by successively examining smaller elements of the link until the box causing the change is located. Scope Creek (TEP) results proved that the backbone structure met the SYPAC criteria and was a viable, assessable, and

controllable element, even over a 1600-mile portion of the backbone structure incorporating 21 RF links. The principle technically can be applied to any large segment desired, although the operational problems of using the data constructively much beyond 20 or 30 links make longer paths marginally useful operationally although still theoretically and practically valid. The above described end-to-end audio technique for assessing a total link has been applied to microwave, tropo, cable, satellite, and other multichannel structures. Satellites are handled as only a slightly unusual microwave link.

It is this worldwide assembly of interconnected microwave, tropo, satellite, cable, etc. equipment that is generically grouped as one of the two major subdivisions of the communication system. It is called the backbone structure for an obvious parallelism. The backbone structure carries or supports all of the communication services. In some industry and trade documents the term"transmission media" is used. The two terms are not synonymous because the term backbone structure extends past these wideband components and includes narrowband elements such as ground/air radios and base cable plants. The backbone structure encompasses the entire user to user interconnect structure.

2. Networks

The second basic subdivision needed to permit the creation of a system control concept, also emerged during the TEP measurements. Several special trouble-shooting activities were carried on by the author

concomitantly with the TEP effort measurements. It became clear, with no sophisticated analysis, that when the backbone structure was stable, troubles with customer services were quite easy to isolate. Whether the fault lay with the terminals, the switch, the operational procedures, or equipment such as the crypto, the trouble was amenable to straightforward fault isolation. The question, then, in completing the SYPAC concept was: could these customer interconnections be approached in principle like the backbone structure? Could the analysis and characterization start from the box level and cumulatively examine and measure larger portions until the entire structure was characterized? The reciprocal approach was also needed - changes in the total structure measurement values had to be capable of isolation by examining ever smaller portions of the total until the box causing the change in readings was located. Scope Creek suggested that these criteria were met by subdivisions such as Autodin, Autovon, and special command and control interconnections. These customer interconnections are called networks. This term is generally recognized in industry.

The elements of a network were studied and understood and included an assortment of terminals of a variety of capabilities, interconnected directly or through one or more switches. Some networks were bi-directional, other networks were broadcast one-way information flow type. The type of network was not the determinant of the basic principles concerned for network assessment and control. The network results can be analyzed, in consonance with the backbone data to give precise status data on the total operational network. The network concept was proven by both manual methods

and ATEC automated measurements. Special test procedures, for terminal, network and circuit assessment and necessary sensing of test points were used by the author, however, all SYPAC principles are valid and are suitable for automation. It is also obvious that tactical gear that must function into the DCS, or through DCS networks must have some of the same testing capability if operational effectiveness is desired. All probably cannot be afforded for weight, space, or mobility reasons, but the key portions must be included.

C. <u>SYPAC System Elements</u>

The total system that requires control is more than the wideband portion, or the numerous networks or the DCS. The total system is the integrated communication entity, user-to-user. Everyone generally agrees that this customer-to-customer view is the only one that can really address the system problems. However, few people ever work on the total system, but are assigned to consider some small sub-element. Their decisions are optimized for that sub-element and not balanced for the entire system. Further, their continued study and work increases their expertise in the relatively small area of assigned duties, but the system view often actually narrows. In order to portray the total system vista, for those who read this SYPAC volume, the following eight major system elements are enumerated in Table 3-1. All of these eight categories must be addressed if the system is to be assessed and controlled. If one sub-element is omitted, the considerations must be incomplete. A short explanation of each of the eight SYPAC System Elements is given below.

Item I, under both the Backbone Structure and the Networks is Hardware. These two elements relate to assessment and control of the hardware boxes. This includes optimization of the basic equipment to 'like new' performance. It includes all of the assessment and control of the normal and special maintenance repair and alignment actions necessary to keep the hardware at proper performance capability. Satisfactory hardware conditions alone, however, <u>do not</u> assure satisfactory system performance, but unsatisfactory box conditions absolutely preclude proper system operation.

SYPAC SYSTEM ELEMENTS

Backbone Structure	Networks
I. Hardware Assessment & Control a. Wideband b. Tail paths c. Base Cables II. Operations Assessment & Control a. Wideband b. Tail Paths c. Base Cables III. Link Performance Assessment & Control a. PMP type channel assessment b. Test tone signal analysis c. User tone signal analysis	I. Hardware Assessment & Control a. Terminals b. Interface devices c. Switches d. Trunks e. Circuits II. Operations Assessment & Control a. Terminals b. Interface devices c. Switches d. Trunks e. Circuits III. Basic Network Assessment & Control a. Terminal signal analysis b. Switch signal analysis IV. Network Performance Assessment a. Customer Service Assessment V. Network Optimization a. Network Control 1. Terminal configuration 2. Switch configuration 3. Trunk configuration b. Traffic Control 1. Terminal control 2. Switch load control 3. Switch routing control 4. Trunk control and directionalization

Table 3 - 1

Item II, under both the Backbone Structure and Networks is Operations. These two elements cover, not the absolute condition of the hardware, but those operational adjustments and matters that influence the operational suitability of the backbone structure or the networks. For example, lack of cards in a cardpunch precludes operation even of a hardware perfect terminal. Levels adjusted by the operator from the front panel to an improper level can degrade or destroy a terminal operations and high customer levels deterioiate the radio links.

Item III, under the Backbone Structure is the assessment and control of the links (single or multihop) as they actually perform in the field. The assessment results obtained in the III Link portion are the sum of I and II. This is true only if the basic engineering of the backbone structure is proper, and the installation is acceptable. Thus assuming that the backbone structure was properly operational once, SYPAC control elements I, II, and III will assess and control the structure correctly. An adverse shifts in either I or II, will show up in the III Link Assessment. Conversely, any degradation in III, can be further isolated to either matters under I or II.

Item III, under networks, is functionally similar to the link portion again assuming that the terminals, circuits, all interfacing devices, etc., are properly engineered and installed -- the Basic Network assessment ascertains degradation within the net whether hardware or operations. It must be noted that this element does not assess customer satisfaction. A network may be operating precisely as designed, and still be unsuitable for the customer needs. Network components may be perfect, but they may be

improperly trunked, or the terminal may be incorrectly sized, etc. Network element III is to assess the actual performance of the network as it is installed, and this concentrates on operation and maintenance matters.

Elements I, II, and III, of both the backbone structure and the networks describe matters that are the responsibilities of the O&M Agencies, although the status is of interest also to DCA.

Network element IV, assess the service provided to the user. Network element III, provides status of the network, thus any degradation or inability to satisfy the user can be correctly attributed to the cause. If I or II are the cause, then these network elements can be fixed. If I, II, and III are proper, but IV is not, then the various network optimization actions tabulated in element V must be considered. After imposition of any selected network or traffic control action, element IV is the feedback assessment to observe changes. Modification of the optimization actions may be required if the changes are inadequate or inappropriate. Obviously, if all customer services are proper, there need be no rapid control actions taken, although moulding for longer term optimization may be needed. If all the backbone structure is proper -- as assessed by backbone element III, and all the network is proper as configured, again as assessed by network element III, there is little more direct initiative that can be exercised by the O&M Agencies. If Network element IV indicates that the structure is meeting desired customer service, DCA need not move, and V class controls are untouched. Clearly, such ideal conditions will rarely occur, and assessment and resultant control must be applied to all elements and

their subordinate subdivisions in proper time correlation, in sufficient intensity, with proper analysis and follow up, if reasonable system performance is to be achieved.

Figure 3-1 portrays in simplistic form, the closed loop assessment and control for the backbone structure, the closed loop assessment and control of the networks -- each more or less independently of other. The status interchange line between the backbone structure and the network analysis complexes, however, permit more intelligent backbone structure control decisions -- and permits the network control to achieve a broader base of data so that the net control site is in addition to its network control functions also a true system control focus.

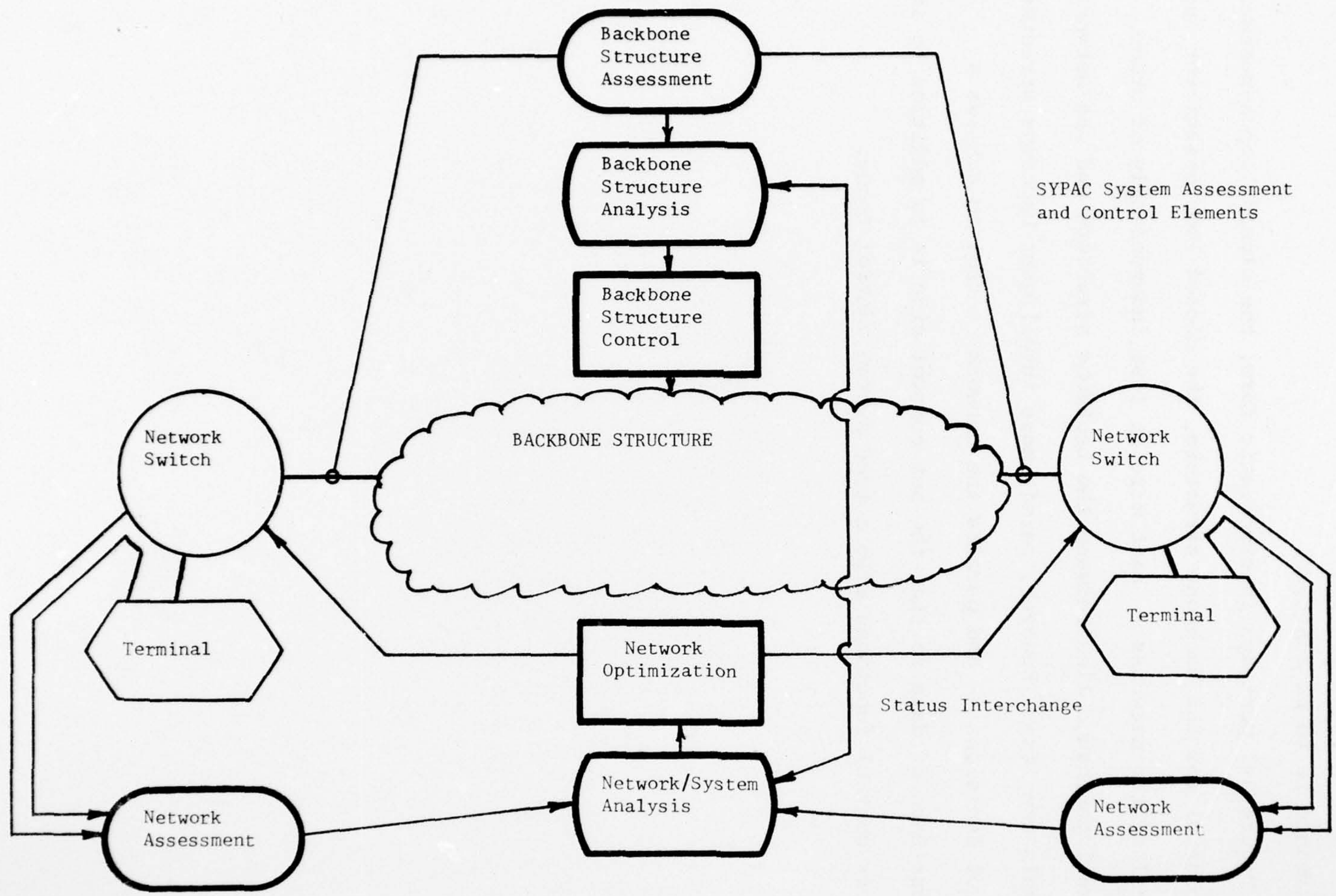

SYPAC System Assessment
and Control Elements
Backbone
Structure
Assessment
Backbone
Structure
Analysis
Backbone
Structure
Control
BACKBONE STRUCTURE
Network
Switch
Network
Switch
Terminal
Terminal
Network
Optimization
Status Interchange
Network/System
Analysis
Network
Assessment
Network
Assessment

Fig. 3-1

IV. BACKBONE STRUCTURE

A. Backbone Structure

1. Theoretical Basis

Earlier it was stated that a box, a link, or a multi-link assembly could be assessed, and that the measured results were practically meaningful. This is not just fortuitous. The scientific basis is quite simple. All experienced microwave engineers have used the NPR (Noise Power Ratio) test to evaluate the quality of a radio link. The technique is used on microwave, tropo, satellite, and wideband cables, etc. The approach is that the radio is loaded to full communication capacity by a special signal generator. The signal is white noise "to simulate the multiplex baseband signal normally provided to the radio." Selected measurements are made at the receiver output that give very valuable information on the equipment basic noise floor, propagation noise, cross talk, intermodulation distortion, feedback and other parameters of interest. It is the radio performance quality indicator recognized throughout industry.

In the military communications backbone structure, information flow is always observable. Encrypted traffic is present full time to preclude certain type of intelligence data extraction. Most of the day, the traffic reasonably approximates full loading, or close enough so that measurements made on the radio can be extrapolated to equivalent fully loaded conditions. The radio however is not the only source of noise, cross talk and intermodulation. In microwave links it normally is the multiplex noise that is limiting. In an operational link, the multiplex assembles all of the

various voice and data signals into a composite baseband signal. It is this real life composite signal that is simulated by the NPR test set. It is obviously possible to use real traffic already flowing to represent itself in lieu of the white noise test set. The real life traffic generates within the radio the same conditions for measurement as the NPR test. A terminated voice channel at the send end provides a 4 KHz slot free of intentional signals for measurement of noise and intermodulation at the receive end. This parallels exactly what the filters do in an NPR test. Thus a true in service NPR test is conducted in the field and the measurements include not only the radio and path noise, but also the other serial intermodulation, cross talk and distortions that occur in the multiplex, line conditioners, cabling, etc. Thus a complete audio-to-audio NPR measurement results. This is what the customer sees, and this is what the system controller must manage.

The author was the first one, to his knowledge, to use measurements made in an idle channel to assess the "in-service NPR performance" of a communication structure. This measurement can be as precise as the out of service NPR test. Since it measures more equipment in series some selected noise sources may be masked, but it is absolutely precise in its assessment of the condition of the actual channels over the path of measurement, audio to audio.

Once this valuable and viable concept was understood, the expansion of the parameters needed to practically characterize a backbone link 'in service' came rather easily.

As explained above, noise in an idle channel in an otherwise loaded link gives one link parameter. This reading presumes that all the channel signal levels are correct. This is a poor presumption, and all levels must be checked. This in itself is a salutary action. Impulse noise must be measured since it is not related to the idle channel noise unless the noise is gaussian -- and for practical purposes no channel exhibits gaussian noise. Phase jitter must also be measured. These four measurements are sufficient to characterize the channel performance with a high likelihood of practical suitability. This characterization, if indicative of of a trouble condition, however, does not assure complete analysis and intelligent fault isolation. Thus, the demands of system assessment require 3 additional parameters. Baseband loading is needed to assure that the composite signal presented to the radio by the multiplex is at or below the radio design level. Frequency off-set is measured to be sure that the multiplexes are in sync. The radio receive signal level (RSL) is needed to help assess the RF portion of the link. Further, there is a precise relationship between the idle channel noise and the RF signal strength for a correctly operating radio installation. The interrelationship permits conversion of idle channel noise and RSL measurements taken at the same time to absolute hardware performance numbers. These factors are related using the radio receiver quieting curve to which has been added the multiplex noise and a factor for baseband loading.

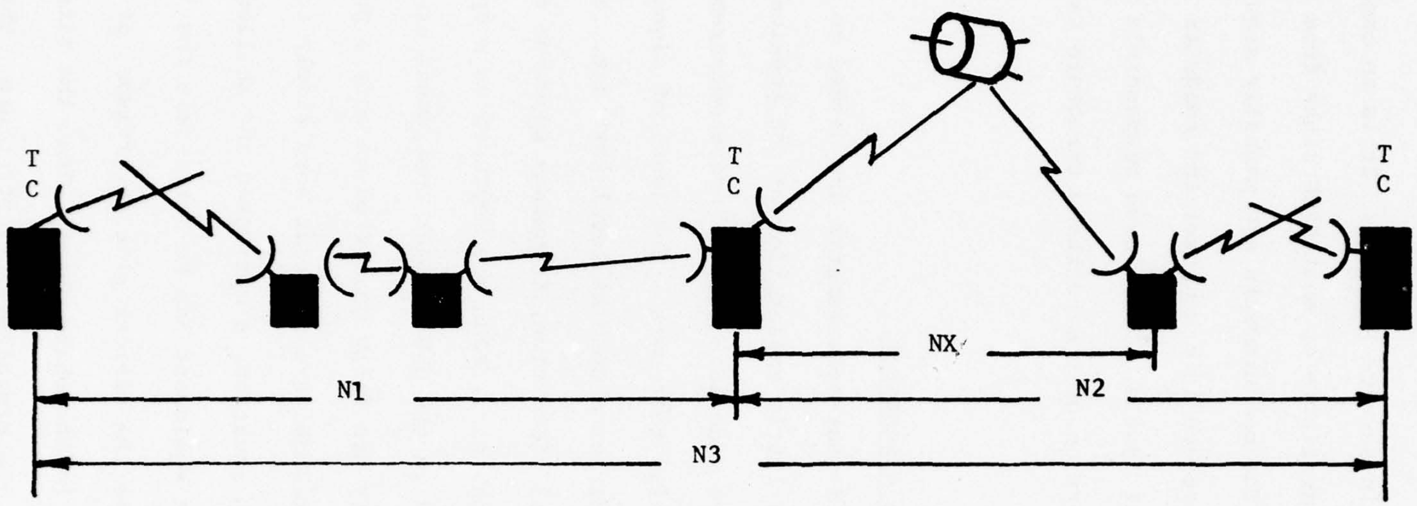
The in-service NPR further allows identification not only that a problem exists, but precisely how much the performance is below the

'like new' standard, and gives specific data helpful in pinpointing which portion of the link has trouble. The capability is increased if similar measurement data is available for the reciprocal path. These parameters assess the status and performance margin of the backbone structure links. If these parameters are all 'like new', the link has a high probability of premium performance.

Figure 4-1 summarizes this assessment approach. Assessment N1 is pictured as measuring from tech control to tech control over a tropo and two microwave links. N2 is measured over a satellite and a tropo path. An N3 could be made including both N1 and N2 paths if operationally desirable. The N1 plus N2 measurements would equal N3. In fact, any tech control where audio breakouts are available can be used to measure to any other audio breakout.

There is nothing either in theory or in practice that precludes the application of these principles to non-radio links, including undersea cable paths, commercial circuits and base cable plants. As will be discussed later, base cables and the human introduced degradations in the cable plant are often the worst part of either a short or a world-wide circuit. In fact Air Force standards permit the same noise contribution for a base cable run as the DCS standards allow for 100 radio links. Obviously a quieter cable plant standard is required. -50 dbmØ would be a reasonable and achievable objective. The cable plants would still limit the performance on short paths, but at a better figure, but would not further degrade the longer circuits.

BACKBONE STRUCTURE ASSESSMENT



A. Idle Channel Noise

B. Impulse Noise

C. R F Signal Strength

D. Base Band Loading

E. Level

F. Phase Jitter

G. Frequency Offset

Fig. 4-1

The AFCS Link Assessment Program (LAP), later the DCA PMP, is an operational embodiment of the in-service NPR test. It is an ongoing Measurement Program with data available on most AFCS links from the fall of 1970 to the present time. The measurements are manually acquired and reported. The data is processed in a computer and readouts are presented to all requiring organizational levels. Thus, each responsible management agency has a picture of the portion of the backbone structure assigned to it, but not in real time.

2. Automated Performance Assessment

This study has stated what measurements are needed to assess the backbone structure. There was little explanation of the physical steps involved. All technicians have made idle channel noise measurements using one or more of the standard noise test sets. The level of signals can be measured on the same noise meter or a special level test set. The phase jitter, RF signal level, signal distortion, frequency spectrum display, impulse noise, delay distortion, etc., each are measured on a special test instrument. Personnel skilled in the use of each instrument are required. Tech control personnel normally are fully qualified on only a portion of these meters. Maintenance personnel are somewhat more widely trained. There normally will be at each location, a motivated and skilled technician who can handle all of the test equipment and he buttresses the less skilled personnel. This will rarely be the officer site supervisor, or NCO in charge, and not often will it be the shift chief. Thus the site technical strength is rarely related to the organizational structure. The formal

and published organizational charts describe only the route for clerical and administrative actions. If this unusual technician is not present at a site, the mission performance always falls. This is the case more often in the last few years. The lack of prowess with test equipment does not reflect a lack of ability to think or reason, but test instruments require knobs in the correct position, an appropriate sequence of measuring events, followed by an interpretation of the meter reading. Some of these are not subject to resolution by generalized knowledge. In particular, it requires a true professional to grasp the meaning behind the standard noise meter indications. The meters give only small kicks when impulse noise is present, because inertia damps the needle excursion. Tests have shown that a 2 db needle kick is approximately a real 20 db impulse when examined by an accurate impulse measuring device. A 5 db kick means that the impulse noise peak levels are approximately equal to the desired signal level. Yet average tech controllers and maintenance men with years of experience still report "no real impulse noise, hits of 'only' 5 db."

SYPAC will be able to make all needed measurements quickly and automatically with no manipulation of knobs or switches, and no set sequence of manual events required. There may still be some interpretation of the measurement results needed, but most analysis can be programmed into SYPAC so that the printout can give the answer needed for management alert. Personnel of the future will not need to master a myriad of test instruments, but will need to learn only to interrelate with the computer heart of SYPAC. Then, the operation and maintenance personnel can concentrate on basic

system matters rather than learning and mastering rote test equipment manipulation. SYPAC automated data gathered in a few seconds will replace 20 minutes of work by an expert - 30 to 40 minutes by more nearly average personnel. The SYPAC automated data will be accurate, the data manually gathered maybe, but often has self-introduced noise from cables, connectors, or faulty terminations, etc. The manual readings are recorded and historical data is lost. Normally only one circuit at a time is addressed because of numbers of test equipments available. SYPAC can provide nearly real time semi-continuous measurements on 20 to 40 separate troublesome circuits or devices, although presently management cannot react to this rate of addressment and the results can be stored in memory. Such a rapid rate is mandatory if a war time rate of recovery posture is to be achieved.

For those who may never have seen an automated assessment printout, Fig. 4-2 and Fig. 4-3 are examples from ATEC. Fig. 4-2 is the routine narrative scan printout. The C msg noise (WN) is 59.7 G (for Green). It is also evident that the noise is not gaussian - as no real life noise ever is - because the difference between C msg and 3 KHz (WF) weighted readings is not the gaussian predicted less than 2 db. The printout records the time of the measurement. All channel parameter measurements are calculated by the fast Fourier transform using the same sampled data so no question exists whether there was a change between the various measurements as is normal with manual meters. Further, the printout labeled NF indicates the predominant noise frequency if there is one. A channel spectrum analysis

ATEC NUMERICAL PRINTOUT

radio day (raday)

Special noise
weighting measurement

GMT time

Circuit
Number

```
RH NC+10.8 I      223/1315   015
AV-55.3      NF+0100     WN-59.7G      FN-56.3      WF-56.9      NC+10.8 RH
```

The 50 and 100 Hz
power hum is 10.8
db larger than the
noise around it in
the channel

Idle channel noise 3KHz flat weighted

Idle channel noise C message weighted

This shows that the predominant noise in
this channel is 50 and 100 Hz power hum.

Idle channel noise average power
unweighted across the 4 KHz bandwidth.

Fig. 4 - 2

ATEC SPECTRUM DISPLAY

```
! MI,7,2,3

C   WN-52.0 I  224/2327 007
AV-49.6     NF+0000     WN-520G     PN-48.9     WF-50.8     NC+00.0
 P1+01.4     X5-49.2
VU-49.2 PA+08.9 SW+1578 FR+0973 M5+00.8

        SPECTRUM  6----5----4----3----2----1----0----1
          01 -59.0*
          02 -64.9
          03 -66.0
          04 -67.6
          05 -67.1
          06 -66.3
          07 -65.7
          08 -65-9
          09 -62.5
          10 -58.1*
          11 -63.1
          12 -62.0
          13 -60.7
          14 -66.5
          15 -68.7
          16 -68.9
          17 -67.6
          18 -61.9
          19 -63.1
          20 -68.5
          21 -68.1
          22 -64.7
          23 -59.9*
          24 -60.8
          25 -65.3
          26 -67.8
          27 -62.8
          28 -58.3
          29 -62.9
          30 -69.4
          31 -68.9
          32 -66.9
          13 -64.0
          34 -61.9
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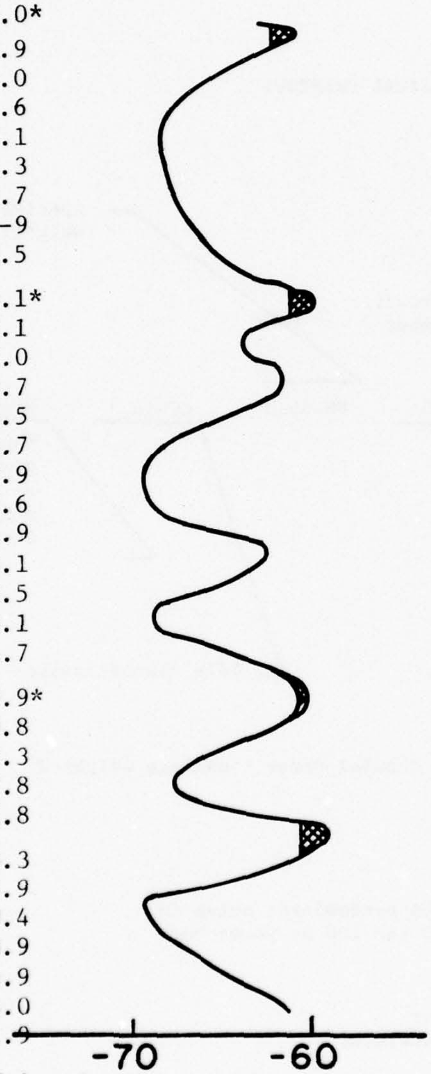


Noise Contribution in each 100 hz filter

Noise in db

The cross-hatched areas correlate with asterisk printouts indicating noise, tones, or intermodulation products stronger than -60dbm∅. There are other tones that are present that fail to reach -60 dbm∅ and so fail to print the asterisk.

Fig. 4-3

is always made and if matters of import are disclosed, the software controls the display of the appropriate data. In this printout the idle channel noise measurement was limited, not by gaussian noise but by a tone at 100 Hz, clearly second harmonic power hum.

Fig. 4-3 shows an operator requested ATEC plot of the spectrum analysis for a channel. The data for the spectrum display was calculated in the computer, in time consonance with the other parameters. The two weighted noise readings disparity showed the presence of at least one tone. The spectrum portrays a much more involved picture - 4 tones stronger than - 60 dbmØ, denoted by the asterisks. The author's hand drawn plot shows the presence of additional tones, 7 in total. A simple noise measurement would disclose none of this informative data. The basic noise floor is about -65 dbmØ, in this not unusual channel, and portrays a noise spectrum that was not known by tech controllers or maintenance personnel. The spectrum display is very informative and is crucial in the analysis of many system problems. The SYPAC concept will also use a printer functionally similar to ATEC although it may not be a teletypewriter as shown here. Quite likely a cathode ray fast readout device will be used where long term recording of the information is not needed and a hard copy device when a record is required.

As will be expanded later in connection with Figs. 5-24 and 5-25, most of the backbone structure performance assessment will come as a direct by-product of assessments performed upon Autovon trunks and other networks channels. There will be little routine need for link channel by channel

measurements with the concomitant requirement for periods of 'out of service'. In essence, the Autovon multi-link trunks are analogous to the N3 multi-link on Fig. 4-1. If there is no indication of degradation, there is no reason to fret about link N1, Nx, or N2. The number of Autovon trunks over most DCS paths is adequate to characterize the path. The degree of detail described in this study on the backbone structure is considerably truncated, since the DCA has already implemented the LAP/PMP - in reality a portion of the SYPAC concept, and a number of personnel in each of the services and the DCA are familiar with the basic principles of backbone assessment. This program has already partially stabilized the backbone structure and has aided in the correction of many of the problems degrading the DCS links. The PMP data has exposed some of the poorly designed equipment, located a portion of the sloppily installed hardware, and has raised the level of understanding of the connective portion of the DCS.

There is much more that could be written on the manner of performance assessment, fault isolation, trouble identification and cooperative measurements among several sites to quantify and isolate problems in the backbone structure where the channels do not appear at audio by using channel measurements in the baseband as demonstrated by ATEC. However, these techniques are known to a few expert tech controllers and these procedures will develop rapidly as ATEC/SYPAC is placed into operational use.

As a parenthetical note, during the tests conducted on ATEC in

England, the local tech controllers used the ATEC to attack nearly all their actual operational problems both circuit and maintenance. The results were very helpful in expanding the scope of application and in raising the level of system understanding for both the test team and the local controllers, however an operationally disturbing fact surfaced that caused stress and confusion to the maintenance organization. A system measurement by ATEC could disclose a degraded condition, and further examination would indicate marginal or poor operational user service, <u>even though the Tech Order specified measurements were all within prescribed limits for the boxes involved</u>. This disagreeable fact also upset managers. It results from the loose procurement, installation, test and acceptance practices overlayed by rather poor hardware/system engineering. These box vs system measurement problems have not, and will never be surfaced by the existing logistic system. The SYPAC measurement is not the individual status of a number of boxes, but rather it is the resultant integrated performance of the entire assembly. It also is the performance as seen by the customer. SYPAC will surface many such chronic problems.

B. <u>Backbone Structure Control</u>

Now that there is a concept for quantitative backbone assessment with a sound technical basis and a viable practical embodiment, the question is how can the results be portrayed and used for control by all levels of authority. At the lower levels, of course, assessments can be compared with present standards, and corrective actions taken when thresholds are violated or approached.

Some people in DoD have been worried about the usefulness and validity of using such fixed link standards. This concern was first expressed in relationship to the 6,000 and 12,000 mile standard design circuits used by DCA for establishing basic communication design criteria and apportioning noise and other degradations to the various hardware and path elements of the circuits. Similar concerns were expressed concerning the performance monitoring program, and whether such standards would assure acceptable service by the DCS and whether the 'like new' performance criteria was really necessary, did it just raise the maintenance cost, or did it really optimize the cost effective maintenance of the DCS. The viability and practicality of these standards should be explained. There are several key link parameters, the foremost of which is idle channel noise. Idle channel noise is the sum of a number of sources of noise and reflects predominantly equipment related trouble such as intermodulation distortion.

There is a simple basis in fact, as well as theory, for putting the issue of standards as a basis for control to rest. It is well known that channel noise increases logarithmically with the number of RF hops. Thus in a simple example, see Table IV-1, if the idle channel noise of -60 dbmØ is assumed for all links, the noise will accumulate as indicated; the signal is assumed to be -13 dbmØ in accordance with DCS standards.

TABLE IV-1

No. of hops	Cumulative Noise	Resultant Signal to Noise Ratio
1	-60 dBm0	47 dB
2	-57 dBm0	44 dB
4	-54 dBm0	41 dB
10	-50 dBm0	37 dB
20	-47 dBm0	34 dB
100	-40 dBm0	27 dB
200	-37 dBm0	24 dB

High data rate networks require a signal to noise ratio of about 20 to 23 dB if terminals are 'like new'. Voice is still usable at 20 dB signal to noise. Teletype works at less than 20 dB signal to noise. There are very few circuits or networks in the world extending farther than 200 RF hops, so at that distance DCS design standards are just met. Most well designed and properly maintained links exceed - 60 dBm0 noise performance. Thus, the -37 dBm0 noise, for the longest circuits, is a reasonable and achievable standard. (Recall that commercial microwave and undersea cable paths add in the RF hop count.)

In the above analysis, the assumption was made that -60 dBm0 noise performance existed on all links. Most tropo links provide channel noise of about -60 dBm0, microwave links are generally better and exceed -65 dBm0. Further, few circuits traverse 200 links, with 20 to 40 hops being a reasonable average. Thus -47 to -44 dBm0 is the worst expected noise reading for most circuits, still using the same 'design' standards.

The question now is, can the above rationale be applied in an operationally reasonable way, using link performance criteria.

The degradation standards to be used as a management threshold are based upon 4 years of link performance assessment data. AFCS has picked 5 dB as the degradation threshold. That is, a 'good' link can degrade no more than 5 dB from like new or some correction must result -- a Green link goes Amber at this degradation threshold. If all links degrade 5 dB, the 'long' 200 RF hop circuits give a signal to noise of 19 dB. This would be troublesome to many services. If 5 or 6 links degrade 5 dB to Amber and the rest are 2 to 3 dB down (still green) the long links will still be just acceptable at -34 dBm0 with a signal to noise of 21 dB. Obviously, the shorter paths will be quite adequate. Few circuits traverse 200 RF links, so 3 to 5 dB additional margin would be available routinely.

All standards however must be set, for the high priority and longest communication circuits. These are most often the command and control and intelligence nets, and so the 5 dB degradation standard before the link enters an Amber state is reasonable, realizable, and operationally viable. When SYPAC automatic sensing and reporting becomes operational, 3 dB is a realizable limit. Note that 2 RF hops are 3 dB (twice) as noisy as 1, and 200 RF paths are also only 3 dB noisier than 100.

Degradation of 10 dB on a number of links clearly puts long circuits at -27 dBm0 noise well below an acceptable noise level. Most data services have extensive trouble or fail to operate at the resulting signal to noise

ratio of 15 dB. Even voice is marginal. Clearly 10 dB degradations (10 times too noisy) puts the system Red. Even average length services over the degraded links will be perturbed. Management action clearly is required, even though local services will still be good, and local managers will get no complaints except the one located at a major command HQ where long distance calls originate or terminate. In fact some managers took no action to correct obvious, and often recognized faults, because the local people seem happy with their service, and so the faults lingers.

There was one assumption made early in this chapter that is so universally accepted that it probably fades from recognition as a presumption, and erroneously assumes the status of a fact. That fiction is that the signal level will be -13dBmØ - DCA states $\pm$ 4 dB from -13dBmØ as the specification, but real life facts state $\pm$ 10 dB (one order of magnitude + and -) as the fairly often encountered level excursion, and $\pm$ 6 dB far from rare. In Table IV-1, the 20 RF hop cumulative noise is -47 dBmØ, producing an expected 34 dB signal to noise ratio. If the signal level is permitted to drop 6 dB to -19 dBmØ, the signal to noise ratio degrades to -28 dB. This is analagous to extending the path from 20 to 80 hops. If the circuit were a long one with 50 Rf hops, the same 6 dB signal drop would make some service go marginal, and others fail.

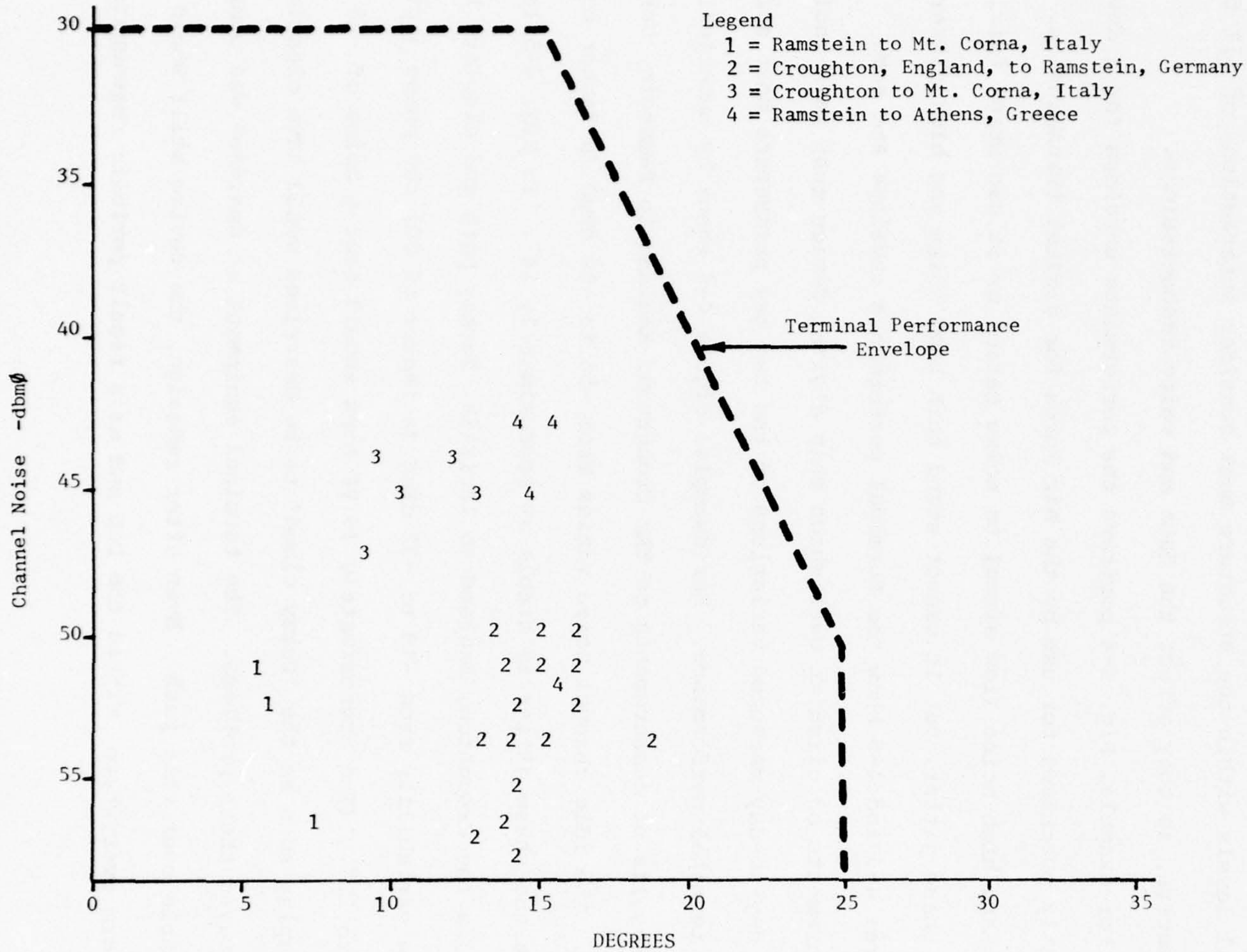
This reduced signal to noise degradations with reduced signal level is well understood by most tech controllers, thus they tend to err on the side of high levels. There is little recognition of the adverse impact of the signal levels 6 dB above the standard. If one user were lucky enough to have the only high signal, he would in fact gain considerably, the 20 RF link

customer would see an apparent signal to noise equivalent to 5 hops. He is however rarely the only beneficiary of high levels. Many others are also high. As a result the cumulative noise is not the -60 dBmØ per hop as 'assumed', but will be some higher value. If the links were fully loaded and 6 dB hot signals were present generally on most signals, the path noise would increase 8 to 10 dB. A general increase in signal levels of 10 dB causes 14 to 16 dB of link degradation. The deterioration does not result in well behaved white noise, but includes higher impulse noise and cross talk that even further degrades the circuit performance. Clearly signal level management is a very important part of assessment and control.

Some people worry why any analysis is ever considered for 200 hops. Admittedly few circuits travel over 200 DCS links but the hops that must transit a leased commercial structure, or an undersea cable cannot be forgotten. Cables for example have design goals such that a 'perfect' circuit would evidence about the noise of 4 or 5 tropo hops, or about 12 'perfect' microwave hops. However, the document listing cable 'ideal' performance capability acknowledged that to achieve such fine performance "implies some selection of the circuits that are to be used for intercontinental extensions." The circuits that start in the conus and travel to an overseas destination, travel over AT&T or Western Union backbone structures that according to Bell studies have a mean noise of near -50 dBmØ. Thus overseas calls encompassing conus links under sea paths, PT&T commercial paths and some portion of the DCS should expect to have performance criteria that approach or exceed that described for 100 links.

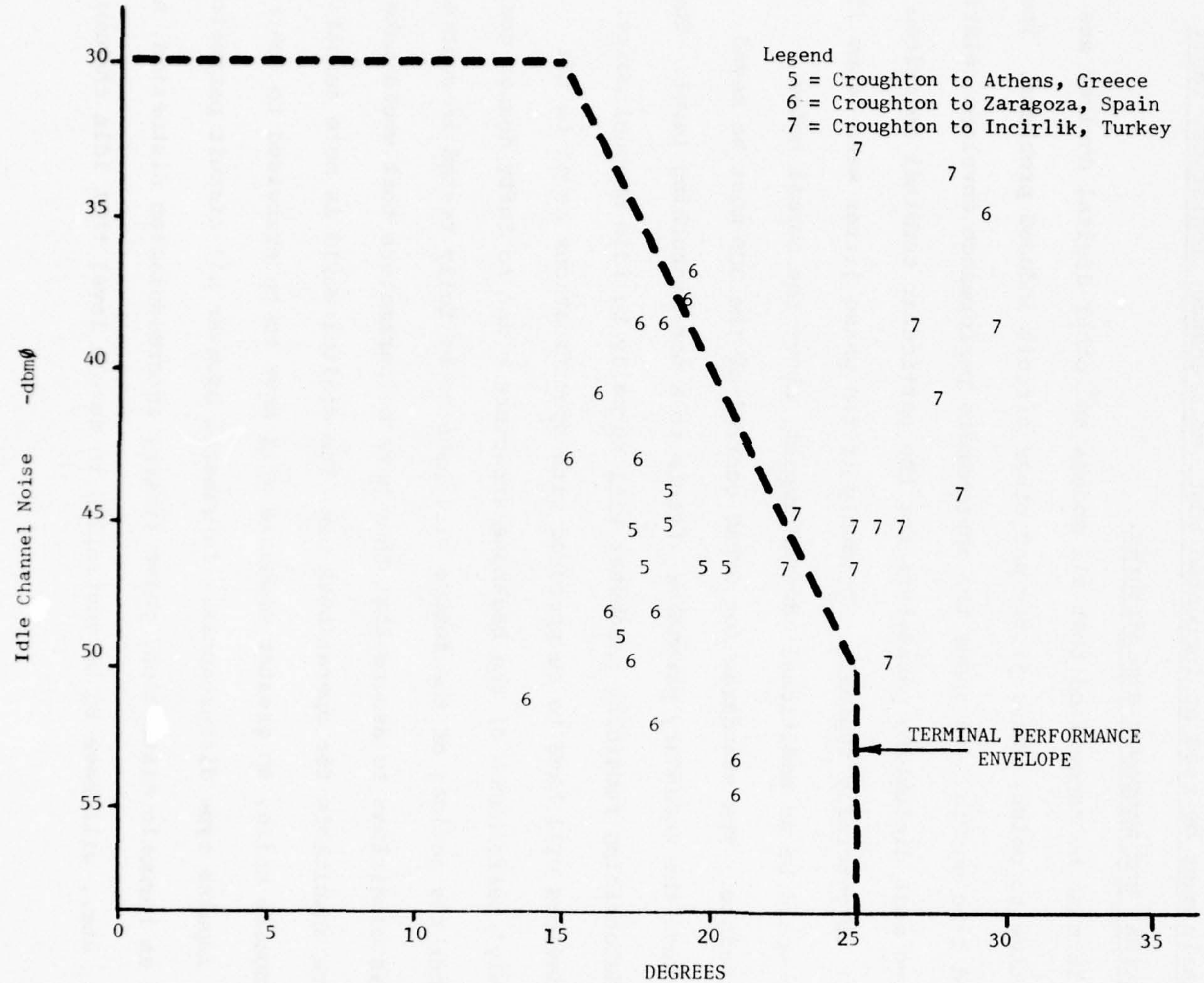
The explanation above appears to be simplistic since it has considered predominantly noise as the parameters that can disrupt communications. Some parameters can be viewed individually but others must be examined in limited rational groupings. The practical establishment of standards, usable at all levels within the structure must consider interactions of all the parameters, as they affect the data and voice transmissions.

For example, Fig. 4-4 portrays the performance envelope for a device recently purchased for use by the Air Force for digital transmission. It can stand high noise (low signal to noise ratio) or it can stand fairly high phase jitter, but it cannot stand both high noise and high jitter. Figures 4-4 and 4-5 show the terminal performance envelope and some measurements on circuits over which this digital device must work including some day-to-day measured variations of the two key parameters most affecting this terminal performance. For example, Figure 4-4 shows by numerical 2's the results of measurements on the Croughton, England to Ramstein, Germany path. The idle channel noise varies from -58 to -50 dBm0 (a factor of six) while the phase jitter is stable at approximately 14°. In Fig. 4-5 legend 7 codes the Croughton, England to Incirlik, Turkey path and displays the noise variability from -49 to -32 dBm0 (a factor of 50) and phase jitter from 21 to 29°. (The approximately 30 RF hops should have a noise of -45 dBmØ.) A display such as the 'fuzzy cloud' to be described would have clearly portrayed these problems. The terminal equipment as designed was completely unusable over this path. Even after redesign, the device still would not perform everywhere within the DCS and as a result periodic regenerators



IDLE CHANNEL NOISE VERSUS PHASE JITTER SHORT LINKS

Fig. 4-4



IDLE CHANNEL NOISE VERSUS PHASE JITTER LONG LINKS

Fig. 4-5

and network restructuring was required. Admittedly, this terminal was not well engineered but then neither are most 'low bid devices'. The DCS is not yet instrumented to measure, limit, or control channel parameter excursions and so allow 'cheap' devices to operate acceptably. The inability to control circuit parameters means that more sophistated terminals must be used at increased cost, maintenance, logistics, fault isolation, and manpower expenditures.

It must be recognized that all modems and other digital devices are sensitive to noise, phase jitter and other circuit induced problems. The dotted line on Fig. 4-4 shows the approximate performance envelope relating the two most disturbing parameters for the particular terminal described but it is generally typical. Obviously if the phase jitter were below 15° there would be no additional adverse impact, above the normal noise constraints. The standards for SYPAC control of the DCS must be keyed to reduce the secondary parameter effects to a non-disturbing level. Thus the determining remaining parameter will normally be idle channel noise. New devices will have to be procured with specifications keyed to the 'likely' performance of the backbone structure - not to lofty design goals. Further the devices of the future will have to be fully tested in controlled stress conditions to assure that they have no parameters that would make the device unsuitable for operational use. The digital world is more sensitive to impulse noise, so greater emphasis will have to be exercised to control such impulse type disturbances. In general however all circuit parameters such as harmonic distortion, phase jitter, intermodulation distortion, net loss, etc., will have to be controlled to such a level that idle channel

noise is the determining performance parameter.

Using this logic the standard for phase jitter, set for the example terminal (and others) would have to be less than 15°. The capability of the multiplex in the DCS to provide low jitter was also examined. The phase jitter shown on Fig. 4-4 and 4-5 was found to be introduced by a poorly designed small component of an older multiplex. There was a simple fix. After the correction this older multiplex was able to provide less than 5° phase jitter. Newer multiplex provide 2° or less. Thus a suitable standard control Amber threshold would be 5°.

The phase jitter is not a random event, so does not add randomly, but is normally 60 cycle power line related. The power line frequency slowly drifts at one station relative to another, so the vector addition of phase jitter results. In most circuits the number of multiplex devices introducing jitter is small, so a 5° standard meets the criteria of providing 15° or less for most circuits. The SYPAC circuit standard is the idle channel noise with the expressed proviso that all other circuit parameters are assessed and controlled at or below established standards. These standards in general coincide with those presently DCA published, but there are some needed changes. The criteria is exemplified below.

		Present Observed	SYPAC Achievable
1.	Phase jitter	± 15	± 5
2.	Harmonic Distortion	> -40dB	> -40 dB
3.	Net loss variation	± 4 dB	± 2 dB
4.	Frequency offset	± 2 Hz	± 2 Hz
5.	Differences between "C" & 3KHzKN reading	5-15 dB	< 4 dB

TABLE IV-2

Since there is a valid theoretical and a practical embodiment of performance assessment, there still remains the problem of presenting the data in a form suitable for control use. The principle is to portray the measured results contrasted with the Scope Creek,test and acceptance standards, or other base line criteria. The key to effective control is to derive a reporting and presentation concept that is simple, precise, and easy to grasp to permit both control actions and also sound overall management decisions. There have been a number of approaches evaluated by AFCS since the PMP data has been available. An acceptable way is described below. The degree of detail required will change depending upon the management level. It makes little difference what type of management actions is discussed, the basic input data is all gathered at a site or at a node. The kind of processing, degree of summarization, frequency of presentation, and required precision may vary. The format of the data may be different to ease visualization and extraction of pertinent management information and the geographical area of coverage will change depending upon the level within the hierarchy. Nevertheless, a rather simple generic format is suitable for all levels of authority and responsibility. It can easily be overlayed with pertinent data uniquely structured for the particular application, yet the format at any level can be understood and used by personnel at any other level within the organization. Such a generalized portrayal is illustrated in Fig. 4-6. Fig. 4-7 is a generalized picture modified to show a backbone view of a specific portion of the structure that approximates an Air Force Group size organization.

THE BACKBONE STRUCTURE

DISPLAY PORTRAYAL

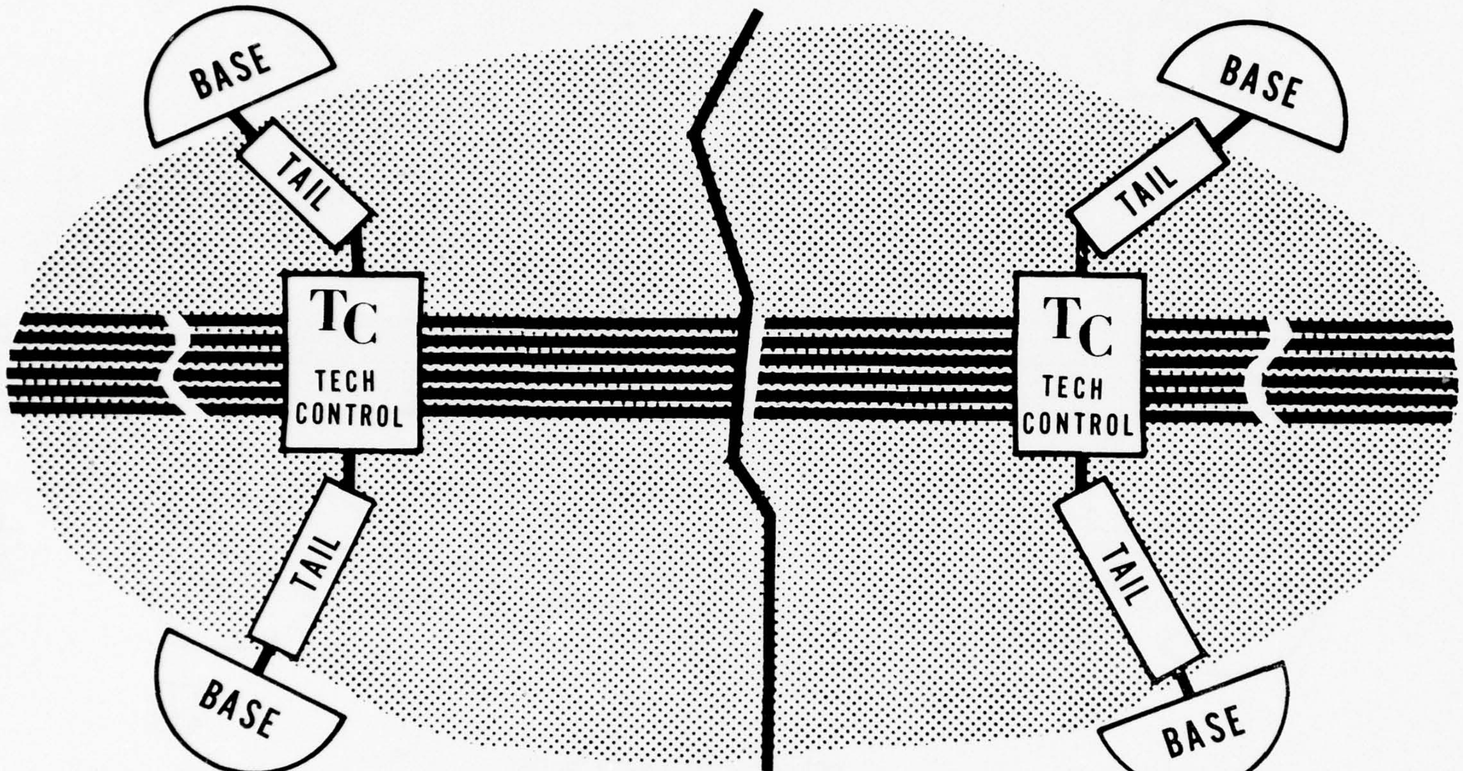


FIG 4 - 6

THE BACKBONE STRUCTURE

GROUP / REGION / SECTOR

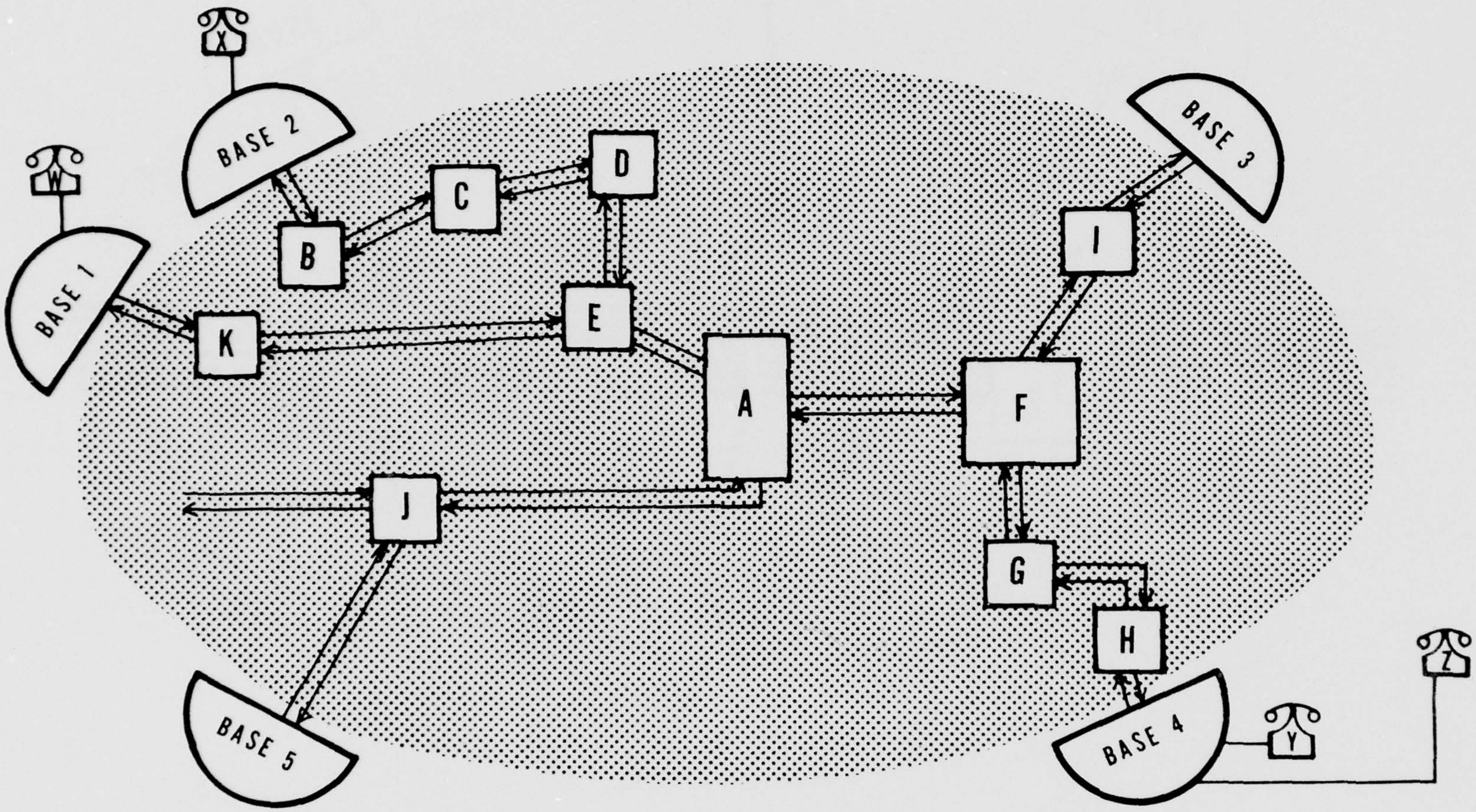


FIG 4 - 7

The backbone structure amorphously pictured in Fig. 4-6 can be facetiously, but accurately, compared with a soft fuzzy cloud through which an aircraft flies. The airplane exits the cloud the same size as it entered, regardless of the length of the cloud. The aircraft departs the cloud undistorted, with but a little moisture added. Nevertheless, the aircraft at the destination is fully operational. The aircraft can traverse the cloud either direction and the results are the same. If the cloud is 'poorly managed' it may be turbulent, or may contain rain, sleet, or hail. The aircraft then can be distorted or destroyed.

An electronic communication signal should exit its backbone structure 'cloud' the same size as it entered, regardless of the length of the path. It exits the cloud undistorted, and with but a bit of noise added. The direction of signal transmission does not change the effects. If the 'cloud' backbone structure is 'poorly managed', the signal may be distorted or may be degraded, or the signal may be lost.

All managers are responsible not only for activities within their area, but also for their portion viewed as a part of an end to end cloud. Arbitrary divisions in the middle of radio hops are not possible. Examination of 'receive' only paths and presuming that the other end will check his receive (and your transmit) have always failed. There will be clearly demarked areas of specific corrective maintenance or operation responsibilities, but performance assessment and fault isolation action -- assurance of premium service -- can never be similarly divided.

In Fig. 4-7 idle channel noise, RSL baseband loading and impulse noise,

are critical assessment parameters for a Region. These could be plotted by the respective arrows to show performance in both directions. The standards would be compared in the SYPAC data processors and only deviations from the standard would be needed, or when reciprocity was not observed. Special notes would be portrayed when phase jitter, frequenty offset, or other anomaly existed. The presentation on this type format is for easy visualization and placement of the problem. For instance, if the baseband loading is high at site C, it must also be high at B,D, & E or else someone has compensated but not corrected the basic problem, and the location can be surmised. Further, the lack of correlation between RSL and idle channel noise should be noted on this presentation even when no network services are as yet perturbed. This will show up false propagation outages, and will permit initiation of corrective action to preserve the full performance margin that exists when all conditions are proper.

It is from this presentation that managers demonstrate to themselves and others that a link must include both ends even though the manager may not have responsibility for both sites: a troubled link incoming to J, can be the fault of the transmission from A, or the reception at site J. Neither site can ignore the trouble until the source is positively isolated. Thus both managers are responsible until one has located the difficulty and has accepted full responsibility for the corrective action.

This analogy clearly portrays why the 'cloud' must be considered as a whole, and thoughts such as "my part of the cloud is OK, it must be your section" are fatal to a traversing signal. This integrated system concept cannot be overemphasized.

As will be covered later, this method of visualization also helps to correlate backbone trouble with network difficulties, assure coherence of events, and keep all possibly concerned managers informed and active until the problem is resolved.

The discussion above has been a partial exposition of tests, measurements, and field evaluations, conducted by AFCS. However, there are many more results that can be derived from the Link Assessment Program/PMP (prototype partial SYPAC). 'Derived' is used specifically because the direct measuremnt of each link can be presented as just described for use by local or Group personnel, but there are also many other ways to collate the data for other management levels. Fig. 4-8 shows a particularly informative and historical graph. The chart covers the performance of a long path from May, 1968, to December, 1975. The chart was first drawn in March, 1971, and the solid line shows the actual measured results to the date. The first measurement prior to Scope Creek showed that this 1500 mile route was performing poorly -- the noise was -37 dBmØ. After the Scope Creek teams had characterized the links, and in the process peaked much equipment, the measured results had improved to -47 dbmØ - one order of magnitude gain. Nine months later, the entire path was degrading and would have returned to the original poor level.

This portrayal clearly proves that the idea of using annual major Scope Creek type alignment of large assemblies must be unsatisfactory as a structure maintenance concept or for management. The data gathered on status always is behind time, the people who cause or fail to prevent

HILLINGTON, ENGLAND TO MT. VIRGINE, ITALY

CHANNEL NOISE

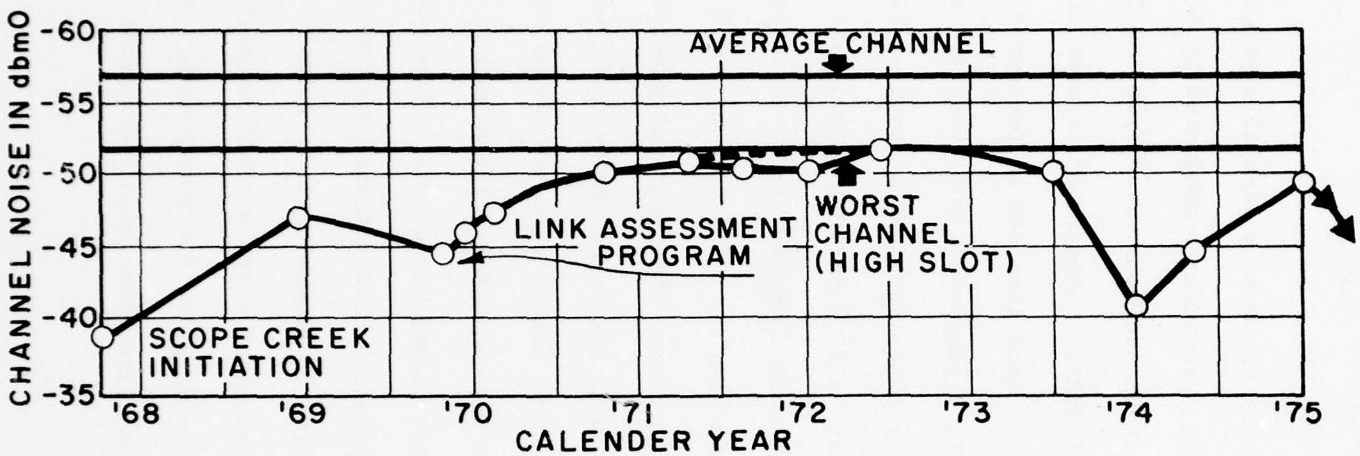


Fig. 4 - 8

degradation are transferred, and the period can never be frequent enough to permit either management or control, and the cost and manpower resources are high and continuing. This major observation was recognized by the author and by AFCS prior to the completion of Scope Creek. The effort and thought that lead to the PMP program and later the SYPAC was the result of searching for a workable and scientifically based assessment concept to provide for day to day performance assessment, management, and control.

Most of the Hillingdon to Mt. Virgine path was included in the AF LAP field evaluation except for a few links maintained by other services. As can be seen, the path immediately began to improve in May 1970 with the start of LAP. The performance gained to -50 dBmØ by mid 1971. The data was accurate and the circles all along the path represent the author's personal measurements to validate the LAP information. The author extrapolated the performance curves in March 1971 and he anticipated that this long link would, by late 1972, perform at -52 dBmØ. The circles and actual performance data did not exceed -50 dBmØ. Most of the links in this total long path did perform well enough to meet the higher figure, but several sites had performance so poor that they were limiting elements. The limiting links were not all those of other services, and the cause of the limiting performance was determined to be predominantly poor maintenance and operation. The group staffs supported by the Area, placed considerable emphasis on the LAP program and by the end of 1972, the measured long link performance slightly exceeded the minimum expected performance level.

Early in 1973, the organization in Europe was subjected to a number of disruptive changes. The Group structures were abolished and the

rapid and informed day to day working relationships with the link maintenance personnel disappeared. The lack of informed direction by the area permitted the increasingly rapid degradation of the links and by mid 1974 the performance was nearly as bad as pre-Scope Creek. Extraordinary Area action including changes in personnel on sites, additional qualified site support activities and supervisory changes reversed the trend, but by the end of 1975, the Area staffs were cut again below any possible hope of total area assessment and control. The long link performance was again headed down, along with most of the European DCS.

The performance of all of Europe can only fall unless SYPAC is installed to provide real time analyzed data to the few personnel left at the wideband Groups and the remnants of the Area staff. The Group staffs will have to be restructured and buttressed to handle new responsibilities as discussed in later sections.

Clearly even the early LAP provided enough information to performance assess and control the European backbone structure to a degree had the organization of AFCS been designed to take advantage of the information. A full seven parameter SYPAC software analyzed report will provide even more information for management. The DCS in place plant can work considerably better if the management structures are reformulated to react positively to control the structure.

V. NETWORKS

A. Network Overview

A communication network is an interconnection, or hookup, of individuals or agencies with a community of communication interest. The geographical extent of a network can be highly variable. A network may be constrained to an Air Base, other nets may have interconnections spread all over the world, for example command and control nets.

Network terminals are the only part of the system that customers normally see. The terminal is connected to wires that disappear from both sight and understanding for most subscribers. If nothing comes out of the terminal, customers may be upset, but it is hard in some cases to know for sure whether something should be arriving. If the terminal is unable to insert a communication into the net, customers are justifiably unhappy. The management problem is simply to be sure that communications can be entered into the network at any time, and that each entry exits the net undistorted,within a reasonable time period. A network manager must be able to assess that these relatively simple performance goals of the whole network are met. If not, he must be able to direct and control the remedial actions.

Network assessment and control is not a new subject. There have been plays, books, television series, and numerous jokes concerning the interplay between the customer and the little old lady at her switchboard, who 'managed' the first voice networks. These little old ladies were frequently slow, they made errors, they listened to some of the conversations, but they

did develop a feel for the circuits, and a rapport with each other and with the customers. Thus they provided a very effective and useful, albeit rudimentary, assessment and control and acted as a workable interface between the electronic portion of the network and the subscribers. The human interface is rapidly disappearing. Operators in the voice networks both here and overseas now are rare. They are being removed from almost all of the communication services for cost reasons and a computer is taking over. Some operators still remain, but only in those areas where the computer seems incapable of doing the job or where the subscriber is incapable of working with the computer. In those cases of human intervention, the cost of the service is higher than its automated counterpart. Bell has put on an intensive campaign to point out the merits of 'Dial One' on long distance calls, and to try to get customers to interface directly into the automated network.

Some networks are predominantly non-time sensitive. The average personal phone call can sustain an hour or more delay and still fulfill the basic need. For data services that are relatively slow and where the information can be repeated with no undue long-term effects, the existing networks provided by the commercial carriers or by individual companies are quite adequate.

There are, however, some networks having to do with aircraft flight safety, reservations for tickets on airlines, or other activities that are at least to some degree time dependent, and these networks often do not perform as well as desired -- and the customer complains. In fact,

because customer complaints may be loud and cannot be fiscally ignored, they are the basis of most of the management of major commercial networks. In some cases, reaction to customer complaints results in improved service for that customer, with annoyance the only long term effect. The customer has his own ears to act as sensors, and he provides his unsolicited assessment free. However, he rarely complains unless his service is entirely disrupted, so he is really a failure alarm. The customer is adaptable in that he accommodates to degraded conditions such as noise, cross talk, and spurious tones. All of this seems quite reasonable to a commercial telephone user, since he has been conditioned to accept this type of service since birth. Still it is a surprise to most people that the telephone companies, not just the Bell System, never really intend to *provide service 100% of the time.* The goal is adequate service 95% of the time. If one were to examine a bit of statistical legerdemain, interesting observations emerge. The service demanded from 8 at night until 8 in the morning is very low, little service is denied regardless of system condition, few customers complain, so 100% availability is recorded. The calls concentrated in the middle of the day can be completed at a 90% rate and still meet the 95% 24 hour service criteria. The commercial companies claim that to really provide 'assured and acceptable' service 24 hours a day would raise the cost of phone service by more than a factor of ten. The author does not believe this. Perhaps it might be better stated, it does not have to cost this much.

Management by customer complaint is standard not only in the United

States, but also worldwide. Conversely, unless a customer complains, he will likely receive marginal service at best, and possibly no service at all. In fact, unless he complains, the phone company may never ascertain that he has no service but will surely continue to bill for these 'not provided' functions.

The military and certain key governmental agencies face a completely different operation. Political and military intelligence information must flow in a matter of minutes since the data is both highly perishable and the information may relate to highly volatile situations. In certain air defense matters, periods of 15 minutes anywhere within the 24 hour clock can be the difference between national survival or demise. In military networks, customer complaints are an unsatisfactory method to initiate network management. If this country failed to receive notification of a ballistic missile attack and so made no command decisions or activated no defense, the U.S. identity would be gone. Customer complaints in this context are meaningless. Thus an effective method of network performance assurance is mandatory. Yet, the idea of customer complaints as 'the' network assessment sensor and the proper source of information upon which to base corrective management is so deeply ingrained worldwide that most people never even question the concept, and in fact, will argue that nothing else is really required -- "it was good enough for Grandpa and it is good enough for me" type logic. Many communicators accept the customer complaint as an immutable law of nature.

The basic engineering design of all major commercial networks is not

based on providing communications, but rather on providing a 'probability' of achieving communications. It is inconceivable to thoughtful examination that this country and its national survival is based upon the design techniques and hardware approach developed for commercial networks whose communication goal is only a statistical 95% call completion rate -- and even that dependent upon customer complaints. Admittedly, the commercial approach is less expensive, but for critical command and control networks and for special intelligence communication interconnects, customer complaints must be absolutely rejected as a management tool -- it is a badge of failure of management.

The problem is not really that the commercial world provides such poor service, because much of the time the Bell System, with its premium quality equipment, advanced maintenance training, duplication of hardware, and with automatic or remote switching of equipment, actually provides higher than 95% service. The difficulty is that there is little civilian market for the technology or hardware required to assess and control a system to achieve near 100% reliability. Further, the U.S. policy to foster competition among the communications firms probably will do what the policy makers want--provide more 'cheap' service; but no one should believe that it will be better, or more reliable. It can only be worse from that now provided, and it will slow what little effort there is on high quality system assessment and control. Thus the military will have to go it alone.

The problem of providing guaranteed service is an acute one on all networks and systems of non-trivial size. As the networks become larger,

the problems increase. If the network is hardwired, that is, where circuits remain fixed between or among specific subscribers, and circuits must be manually patched to modify the interconnection, the assessment difficulty increases less rapidly. Airline reservation nets, where all terminals always connect to a single large computer, are examples of hardwired structures. The leased circuits may be rerouted by the carrier, but the entry and exit points remain fixed, and the customer provided hardware remains unchanged. Many modern communication networks demand much more flexibility than a hardwired net and so these structures incorporate switches. These switches upon demand interconnect selected members of the net as required at that time. The route through the network on any two sequential calls even between the same subscribers, will not often be over identical paths, nor will it use the same electronic boxes. The switch selects the route by a software logic normally intended to optimize facility utilization (not call completion) and it concomitantly maximizes the permutations of equipment and circuits used to complete the interconnections. Consequently identifying a problem and its subsequent resolution in a switched network is many orders of magnitude harder than in a hardwired net. The identification of a problem is compounded for the manager since a replacement of the troublesome call by the customer may give acceptable results and he will not complain. (When did you last complain about a poor AUTOVON or long distance call?)

But if customer complaints are an unsatisfactory technique, what then must be substituted in order to give network managers complete, honest and

reliable status on the service they provide, and give information from which they can derive data sufficient for positive network management? Many people in the world consider in-station message handling time an important criteria. It is a factor since a message that is not handled obviously cannot be delivered. Yet a message is normally delayed often for hours getting to the message center, is processed expeditiously into the automated network and transmitted to the far airbase at a very rapid rate, processed rapidly to a pickup box where it sits before pickup by the recipient. The service could be terrible yet 'in station handling time, could be good. From a network standpoint, in-station handling time switch efficiency or any other partial assessment is useless, unless it is a sub-element that is rationally integrated with all other key factors to form a total network performance assessment.

Some people view the job of network management as related only to traffic analysis - the effort that indicates the number of messages or calls using a particular portion of the network at a particular time. If any portion of the network gets full, network operations degrade and corrective action must be taken. Traffic analysis is, in fact, an important part of network management, but it addresses only one portion of the service. Traffic analysis is a highly useful form of assessment and it is needed to continually mold the framework of a network to follow the changing nature of the user requirements. It presently reacts to the slow ebb and flow of commercial or military needs. The more advanced forms of traffic management will permit restructuring a network in near real time to match rapidly changing subscriber needs. This rapid

restructuring obviously is a requirement of military network control.

Within most present commercial telephone networks, the sensing is done on a relative basis. Many commercial network sensors measure, not the absolute usage of the elements, but rather superficially examine various bottleneck elements of the network to see when they are 90% full, on the presumption that if no knot hole is full, there should be no customer complaints, so why worry. As an example the lack of the 2600 cycle signalling tone on a large percentage of interswitch circuits in a recent notorious commercial instance was the result of malwiring and defective cable installation. As a result all the simplistic traffic sensors indicated highly loaded facilities when in fact there was little traffic. The 'shorted' facilities always indicated fully loaded circuits. The customer got poor service, and the commercial communicator provided a long and erroneous explanation as to why calls could not be processed efficiently. This above logic does not intend to point out that traffic studies are not valuable, but rather to show that present commercial network sensing and analysis approaches do not relate directly and in some cases do not relate at all, to the actual condition of the network, and frequently misinform and mal-educate managers. These approaches are unsuitable for the national survival DCS.

Some people state that the computers which are the brains of modern switches have built-in soft or firmware routines that assure that there are no switch equipment malfunctions. If this were really correct, perhaps the switch would operate acceptably; but there is far more to a network than

just the switches, and perfect switches do not assure acceptable network performance. But even this switch self-check presumption is wrong and can never be true. Switches perform certain self-check routines and also run certain sampling criteria to identify selected faults, but only those faults anticipated by the designer of the switch. These self-check routines also can check certain peripheral devices, and in limited cases the communication paths among switches. However, field experience shows that the engineers who design switches do not understand field problems and cannot be expected to recognize most of the hundreds of possible degradations and faults in a network that occur in operational use. For example, during installation, thousands of wires are connected to the computer to interface peripherals. Blobs of solder, short pieces of wire, short sections of insulation, dust, and dirt invariably lodge within this wiring harness. Over a period of time, as wires are moved to meet changing interconnect requirements or during maintenance, one or more pieces of this debris fall and lodge within some portion of the interconnect wiring. These cause troubles, but not always shorts that are relatively easy to find. Rather they generate intermittent shorts and resistances, or high resistance paths where none should be expected according to theory. The number of computer routines required to sort these type problems for every wire is astronomical and cannot be afforded either from the software or hardware standpoint.

When a computer or in fact any digital equipment is new, and after manufacturing defects are corrected, digital signals flow with minimum trouble. Both designers and personnel who run acceptance tests and who have

not had the enlightening opportunity to live for several years in the field with a large digital electronic assembly, conclude that once a digital structure works, all will be well indefinitely. But all electronic equipment -- and specifically not excepting solid state digital boxes -- has a continual degradation with time. Further, interconnect cables, connector, card sockets, etc., all have a measure of time and environment related degradation. AFCS has had experience with several large digital switched networks which are now over 5 years old. No observant individual can long accept the concept "it worked during acceptance test, thus we will have no further problems." There are always degradations and major problems; each software change highlights this even more. Just recently, "several wiring errors in the common control circuitry were located." The errors became evident after recent centrally directed changes were installed and a slightly modified equipment configuration resulted that surfaced the errors clearly for the first time. They had caused problems before, but had not been isolated.

Further, computers and digital boxes are go/no-go devices. The waveforms within the electronics are neither known nor a matter of interest to the designer, the manufacturer, or to most users. Indeed when they are new, it may not be a matter of concern. Cross talk between wires is frequently rampant, but when everything is new the cross talk is down a few dB below decision threshold and so causes no errors in the digital logic. As digital devices age, the capacitors drift slightly in value and get noisy. The transistors change characteristics perceptably. Large scale

AD-A047 896 GEORGIA INST OF TECH ATLANTA SCHOOL OF ELECTRICAL ENGINEERING F/G 17/2.1
SYSTEM PERFORMANCE ASSESSMENT AND CONTROL CONCEPT (SYPAC)
OCT 77 FEIK, ROBERT CONTRACT NO. F30602-75-C-118

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integrated devices modify their performance a little. Heat pockets within certain boxes selectively age some components more than others and the performance margin available 'when new' shrinks. The previously unobserved cross talk may cause difficulty or errors within the system. Connectors get dirty, little bits of wax material and steel wool from buffing the floors are sucked into the electronics and cause further small changes. The digital device, which from a digital standpoint should be infallible now makes 'illogical' errors. If one is lucky, the defect will remain constant in value and time, and can be isolated and corrected perhaps by the built in self-check routine; if not, by some highly skilled technician who will step laboriously through the circuitry to find the point of error -- meanwhile the device is out of service.

Unfortunately, the problem more likely is intermittent and may be the result of not one but several degradations -- each not too significant by itself. A connector with bad pins, a slightly drifted component, and a bit of AC hum on the signal degrades the previous performance margin.
The slightest variation in the signal, environment, or device produces intermittent errors. 'Administrators' cannot understand what can go wrong with digital systems that 'never' make mistakes, or why these problems are hard to find. Meanwhile, the customers are denied reliable service. It has become evident that digital devices may be cheaper to maintain than previous generation hardware over the long run, but in any given time period they defy fault isolation by an average maintainer; and at times are still troublesome to keep at premium performance compared with the analog boxes

they replaced. In fact, trouble shooting digital circuits or assembly of devices, such as switches, is frequently much more difficult and requires a higher skill level than with analog structures.

This does not mean that the Air Force, and in fact the entire communications world, will not advance digitally. The above logic, however, does state that the old, out-moded methods of management, procurement of equipment, and the cavalier manner in which we handled our present networks will have to be drastically modified for the new digital structures. The customer complaint method of performance assessment, present software 'switch only' self-check, will have to be redone. The basic conclusion is inescapable. The simple conversion of the analog DCS to a digital mode will not provide the solution to system effectiveness. The implementation of a digital world by use of unmodified commercial boxes, with no system related modifications, and whose primary box selection criteria is price, will further degrade the overall system performance. Additionally such implementation will assure that every five years or so, these devices and networks will have to be replaced or overbuilt to regain lost performance. The alternative is that the military communication services will face increasing numbers of extended outage times, and will become unsatisfactory for command and control and other time sensitive data interchanges.

Another facet not assessable presently by managers of either digital or analog nets is the prediction of the capability of the network to meet operational needs under stressed conditions. Customer complaints are

always low at three o'clock in the morning. The commercial companies view this matter with complete equanimity, since if no customer is demanding service, there obviously can be no unhappy customers. In a military sense, the fact that no military customers are using the system is unrelated to the fact that within minutes, an emergency could severely stress the system. A commander must know that at any time his system is capable of responding effectively to the maximum design strain. It is of no interest to observe that no subscriber is denied service right now, but then be surprised when the first additional bit entered into the system starts network overload and degradation. There are no techniques, implemented either in military or in commercial use, that even begin to address this facet of the problem.

The question then is how do you assess the absolute capability of a network to handle its maximum design load and do so completely independently of the imposition of that design load by the normal subscribers.

Periodic assessment similar to that imposed during test and acceptance could dramatically raise the likelihood of successful operationally stressed use. This network problem could be better understood by examining a world-wide hypothetical network. Suppose that a new network had its initial installation in 1976 in the Pacific and that it was completed on the other side of the world in Europe in 1977. Hundreds of people would be involved in various facets of operation, maintenance, interconnect, installation, etc. with elements of the system tested sequentially and turned over to operational traffic. Operational pressure (an excuse) has caused acceptance of many marginal and just plain poor devices and dismal

installations into the DCS. The assessment needed is one to assure that the total network as completed worldwide is capable of meeting the design goals on the day it is completely in Europe in 1977. Further that periodically after this test, the total network still meets the full requirements and <u>with the same performance margin</u>. Many of these networks may never be stressed to 100% design load during normal peacetime operations, so they must be artificially stressed to assure the capability of 100% performance in times of national emergency.

It is for all of these above mentioned reasons that network assessment and control must also be addressed as a major specific part of system performance assessment and control.

B. SYPAC Technical

All networks obviously are different in some critical aspect from all other networks. Similarly, all nets have features in common regardless of the wide desparity in functions, and assessment approaches that work on one network can be useful on another in a similar or modified form. The thoughts on network assessment to be discussed in the following pages include conceptually new ideas, extension of present approaches and already demonstrated techniques. All, however, fit together to provide the network assessment capability required.

All networks must have terminals where information enters and exits. All networks have signals that traverse the backbone structure between the input and output elements. See Fig. 5-1. They may have a common node such

SIMPLIFIED NETWORK PORTRAYAL

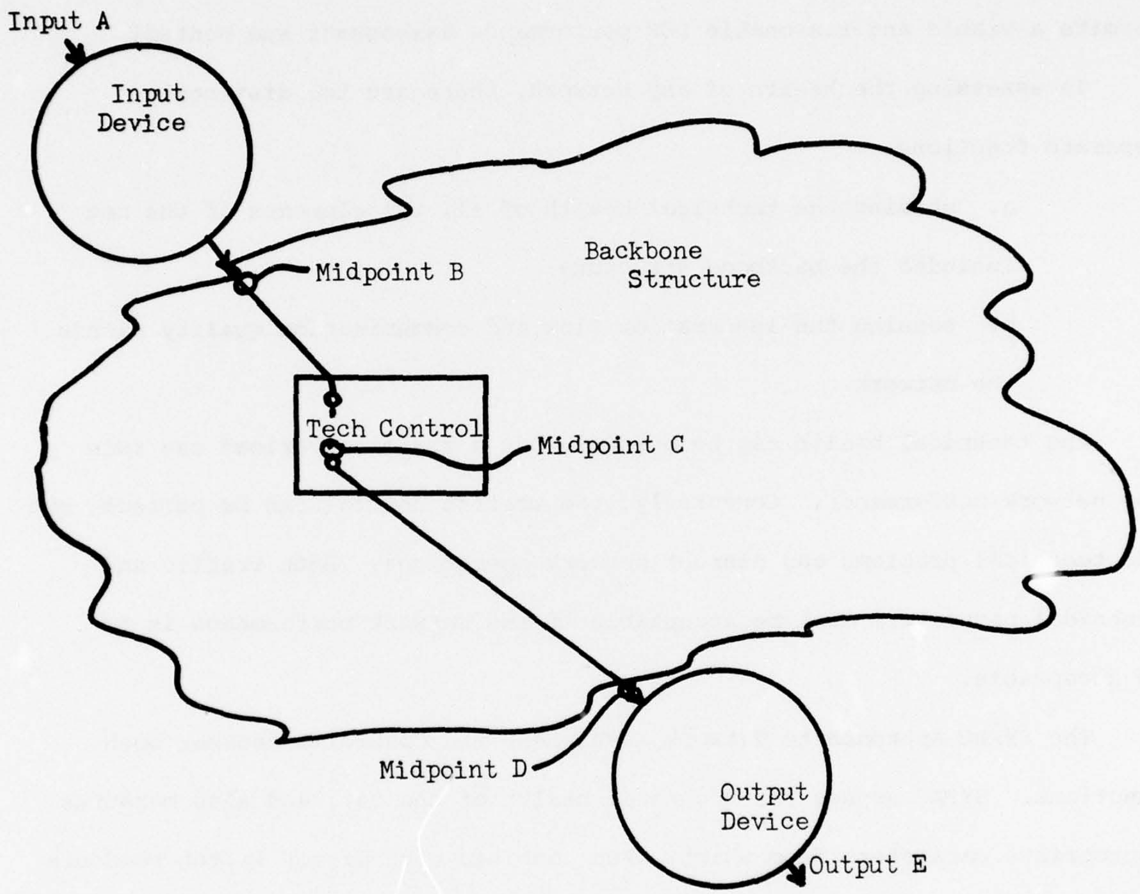


Fig. 5-1

as a switch where the entered data is sorted, manipulated, or rerouted. Quite evidently, people are involved in various facets of the operation and maintenance of the net. It is this commonality of generic features that permits a viable and reasonable DCS performance assessment and control.

In assessing the health of any network, there are two distinctly separate functions:

a. sensing the technical health of all the elements of the net included the backbone structure;

b. sensing the information flow and communication quality within the network.

The technical health can be perfect, but a traffic overload can ruin the network performance. Conversely, the traffic control can be perfect, but the technical problems can disrupt network operations. Both traffic and technical parameters must be acceptable if the network performance is to be acceptable.

The SYPAC Approach to Network Assessment and Control addresses both functions. SYPAC senses the technical health of the net, and also measures appropriate parameters from which, when combined with direct switch readouts, the control of the traffic flow can be derived.

1. Communication Quality

A quick but simple visualization of a network, Fig. 5-1, permits easy recognition of the five prime positions where assessments can be made of the technical condition and performance of the network. If the network performs as desired, the customer signals at A and E should be the same; the signal

format for transmission at B, C, and D should be the same. If either of the these two statements are violated significantly, then the network must fail to perform the mission.

In the case of some analog communications, the signals at all five points should be the same. In encrypted nets, and in the digital world some processing taking place in the network that changes the character of the signal and A & E do not necessarily resemble B, C, & D.

The simplicity of these statements obscures the technical challenge of achieving validation of these criteria in near real time. For example, an input to A can be returned to A for comparison, after emergence at E. Certainly such forms of assessment could be very precise, but would not be cost effective in most embodiments. When the input is narrative, the comparison is tedious and not cost effective if manual, and expensive even if automatic.

There are several conventional ways to indirectly determine whether A equals E. The automatic request for retransmission (ARQ) used by AUTODIN is an accepted procedure used widely. The data to be sent is examined and key characteristics are ascertained. The communication data is then sent through the backbone structure along with added information describing these key characteristics. At the receive end, the key characteristics as determined at the send end are compared to the same characteristics determined at the receive end. If any change in the communication data has occurred, the key characteristic also will have changed and the communication will be rejected and a retransmission requested. This

method is effective, but wastes time and bandwidth, so is not the best way to go in many types of networks.

Another method to assure that A equals E is forward acting error correcting. It is based upon sending the data in a prescribed manner. This special method of transmitting the data permits the receive end to sense when a bit is in error and to extract sufficient information from the bit stream, to correct the bit error. This method is excellent in many cases and can be the basis for a new and effective terminal self-assessment capability.

There is a new unconventional network assessment approach that was not possible until ATEC. The SYPAC concept uses this more modern, much more useful, and more cost effective solution. ATEC has provided hardware and operational validation of this new approach. Ref. Fig. 5-1. Suppose that a conventional 1000 Hz tone were inserted at point A, and it traverses the DCS to point E, technicians in both the military and the commercial worlds would know what to do. The actions would be routine -- check:

a. signal level
b. signal frequency
c. channel noise (using 1000 Hz notch filter)
d. channel harmonic distortion
e. impulse noise
f. drop-outs
g. etc.

The results of these tests after some technician analysis would

ascertain whether there was a problem. The analysis of the readings taken A, B, C, D, and E, would fault isolate any troubles to a link-- C to D for example.

In real life a signal -- a more complex signal-- is inserted at point A by the user terminal, and it traverses the DCS to point E. The parallelism is perfect. Why not use this real signal as though it were a test tone? This approach would then make it possible to perform the necessary network and channel assessment:

a. with no customer service denial while the test tone is inserted.

b. with no personnel at the point A to connect the test tone.

c. no test signal generator.

d. and available at any point without pre-arranged scheduling of maintenance personnel all along the route of interest.

SYPAC will provide this ATEC proved capability. It is strange that few professional communicators really appreciate the immense capability of computer/software based digital filters with software controlled characteristics, and the fast Fourier transform with the software capability to recognize the signal using stored signal characterization data, much like humans recognize other people. Further just as people can tell when someone they recognize is distorted by pain or grief, the ATEC can recognize distortion of a signal and can measure how much. SYPAC

will do increasingly better, as more experience is gained in the field, and as technicians and engineers learn to use the new and vast capabilities provided. Of great importance, each time something new or better is devised, only the SYPAC software need be changed. No hardware replacement, no overbuilds, no discarding of resources. The SYPAC can grow and mature just as the Autodin switch network has grown, by software patches and with periodic restructuring of the entire software program. The hardware basically remained, but the capability increased dramatically.

These matters are discussed more fully in the Integrated System Assessment section of this chapter.

2. Communication Flow.

The network traffic flow in a non-switched network is easy to assess and becomes a matter only of selecting and implementing one of several methods. The traffic flow problem reduces to one of assuring that the terminals are properly sized to handle the volume of outgoing or incoming messages.

In a switched network, however, the determination of the traffic flow among the switches, the congestion in the interswitch trunks, the status of the traffic in the switch, the prime sources of traffic, the destinations of the bulk of the messages, and any queues in the network or between the basic network and any terminal unmatched to the requirement, is a major problem, and one not now effectively addressed in the DCS. Some progress has been made by such overbuilds as the Traffic Data Collection System (TDCS) for Autovon, but the TDCS provides incomplete data and information

that can be in error. SYPAC sensing can make a considerable contribution to network traffic flow assessment.

3. Technical Health of the Network Hardware.

Presently, the DCS extracts certain information on the technical health of the switch. The switch conducts certain self-checks and provides the results on a punched card. The same punch card readout is used to provide in-service assessment reports. In the case of Autodin this card punch readout is busy all day and provides much data. Sometimes the card gives an unambiguous indication of exactly what is wrong, and sometimes the switch operators pick up these cards immediately and convert the punched code to understandable technical terms, and act upon the information.

Frequently the card data is indicative only of a general network problem, but the difficulty can be attributed to a number of causes acting singly or in concert. If the operators do not 'believe' that a major problem exists, they routinely fail to even translate the card. If they do read it, the ambiguity of the printout forces the operator to make additional tests before he can correctly assess the cause and so he routinely disregards these cards or arbitrarily assigns what he believes is a 'reasonable' cause. Most often, the cards are kept for the entire eight hour shift, filed for a period prescribed by regulations and then destroyed or sent to a remote site for analysis. An estimated 95% of the data is never used. Of the remainder, a very small percent is ever correctly attributed to a specific problem and fixed. Many problems in the

switch are not automatically assessed, so the switch status is not fully known. For those who would dispute this, recall the times that switches have remained out of service for matters of hours, or switches that have recurring problems that plague switch reliability for several months or longer without resolution.

However, even if the switches were assessed 100%, that would still cover only a portion of the network. The traffic to the network must input and exit through terminals. If the terminal operation is defective there can be no network performance -- as rated at the defective terminal. The DCS presently has no terminal assessment program. Units that are broken may be reported to the O & M Agency. In some cases, terminals have such a history of failure that an alternate or a back-up device is provided. Thus terminal failure can be compensated by duplication and eventual exchange or repair by the customer, but the failure is unnoted by the network manager. Failure of both the primary and the back-up unit might still go unnoticed unless a special report is sent over some other unfailed network routing. Clearly the status of terminals must receive assessment and control if the network functions are to be managed. The SYPAC study addresses this issue as a matter of high importance, since large cost savings are achievable in reduced terminal number, and fewer maintenance personnel.

4. Technical Health of the Backbone Structure.

The terminals and switches of the network may have excellent health,

and the network hardware resources may be properly allocated to handle all traffic, but if the circuits that connect the terminals to the switches or that interconnect among the switches are bad, clearly no network traffic can flow. The DCS switches marginally address the interswitch connectivity, although primarily on a in-service versus failed basis.

There is no effective assessment of the terminal connectivity. The theory of networks normally "assumes a Poisson or Erlang B distribution" of traffic arriving at the switch -- this fanciful assumption, is made without recognizing the hidden assumption that all network terminals and access lines are degradation free and failure proof. Thus sophisticated scientific attention is addressed to traffic flow and resource allocation studies within and among switches. The mundane matters of attempting to make real life hardware approach the Poisson assumption is left to the field operators. SYPAC directly addresses the network/backbone issue.

5. Network/Backbone Structure Interrelationships.

If the network hardware were 'perfect' and all users were complying with all relevant constraints, any network difficulties would easily be attributable to the backbone structure. The reverse would also be true. Unfortunately, no electronic assembly of any significant size is ever 'perfect'. Some degradation is <u>always</u> present. Thus when a network experiences difficulties, it may be a degradation or failure within the network itself, the backbone structure, or both. Complete failures are

generally easier to detect and isolate. Degradations in the network may not cause maloperation if the associated portion of the backbone structure is in premium condition. Similarly, degraded portions of the backbone structure can be used by properly operating terminals or switches. The degraded portion of a network operating over a deteriorated backbone structure may cause poor or erratic operation or failure even though neither portion is classed as failed. Erratic network operation is evidenced when an Autovon call fails to complete, no busy signal is received, but a re-dial of the call connects quickly and easily. SYPAC addresses this problem directly.

C. Network Assessment Concept and Principles

1. Introduction

Networks obviously have been designed in many ways for many purposes. The class of signal processed through the network, the data rate of the interchange, the speed of completion of the interchange, and the reliability all vary widely. In a detailed way all networks are different, however, there are generically three types of networks. Within each of the classes certain basic characteristics are common. It is these common features that are of interest in performance assessment and control. Further, this tripartite grouping has permitted studying classes of assessment and control schemes.

The networks are categorized as indicated:

Dedicated Broadcast

Dedicated 2-Way

Switched a. normal

b. plus preemption

This portion of the SYPAC study will address, in sequence, each of the classes and will portray the approach to network assessment and control. Some technical matters will be discussed in detail when first raised in the simpler networks, and these matters will not be re-described in ensuing use of that technique in more complex nets. Thus the concept will build and expand until the total approach is clear. As in all concepts, there are several ways to meet certain subgoals. Those described are presently workable, although field experience may suggest added refinements.

2. Dedicated Broadcast Networks

a. Discussion

There are many examples of dedicated broadcast nets, technically the least complex of the networks. The U.S. wide TV distribution structure is one; the various radio networks in civilian life and the Armed Forces Entertainment Network in DOD are examples. The Weather-graphic distribution structure displayed simplistically in Fig. 5-2 is an example of an important military dedicated broadcast network. Weather maps are generated at a Weather Central in the United States into which all raw weather information is funneled and processed. The resultant weather products are then broadcast worldwide. The U.S. and Pacific portions of the network are not covered in the figure for simplicity's sake, but the single

EUROPEAN FACSIMILE NETWORK

(SIMPLIFIED)

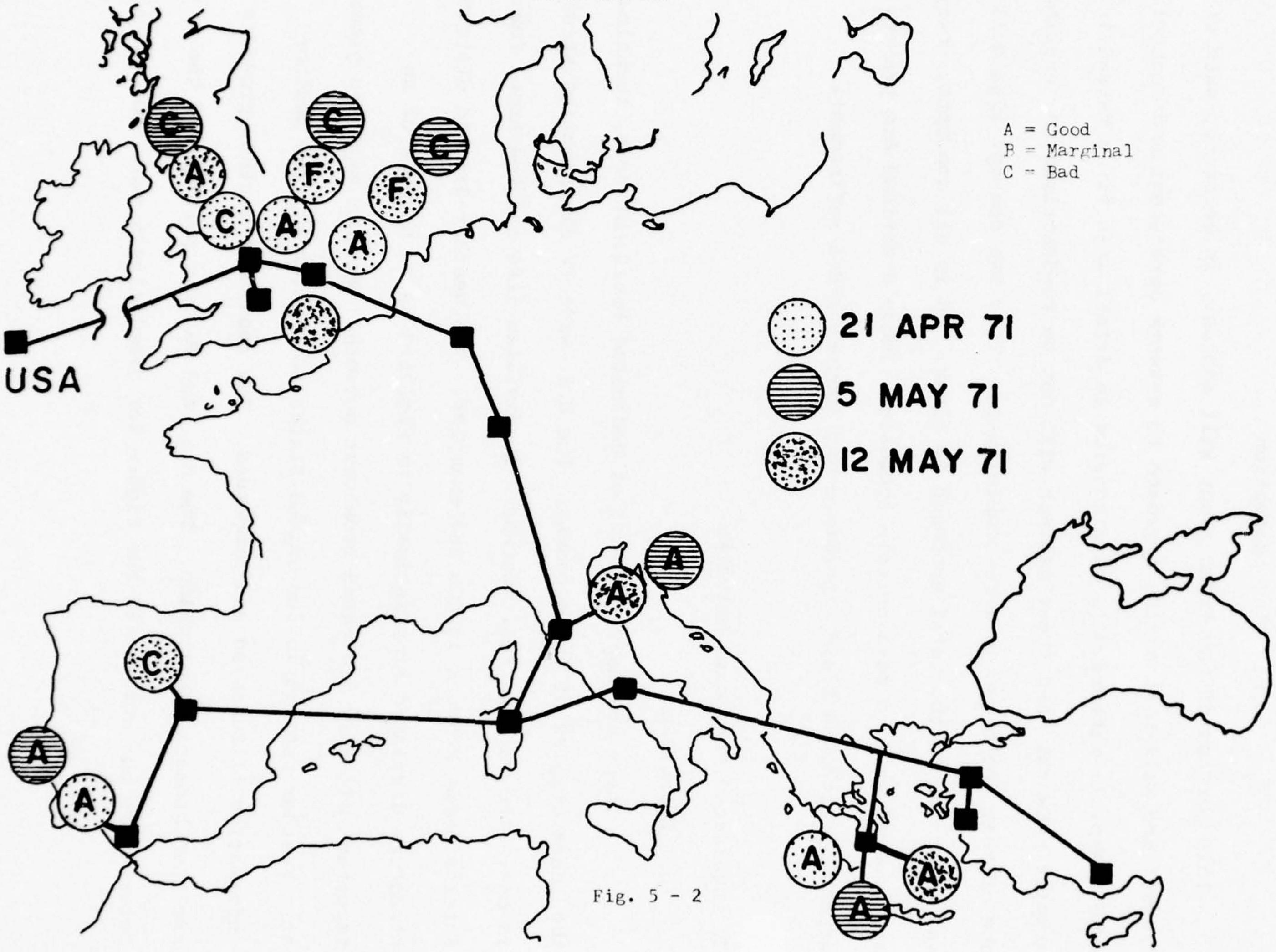


Fig. 5 - 2

thread one way feature is common. Likewise the location of most of the nearly 100 terminals in Europe is omitted. The network expanse in Europe alone however extends a distance greater than that across the United States and is adequate to show the sort of operational problems faced. The weather maps are sent 'in the blind'. It is much like talking into a one way phone. You have no way of knowing how well you are being received. The CONUS Weather Central transmits many products, selected ones of which are needed at the interconnected bases. All maps needed by all of the locations are sent on a prestructured time schedule. The users at the end locations receive the desired maps by time selection or they just receive all maps and dispose of noninteresting data. There is no effective or near real time control mechanism for central assessment to ascertain that the maps arrived at the appropriate destinations or whether they arrived garbled. A site that misses a map and who knows he missed it and needs it, may telephone a central point in the geographical area and ask for a repeat map broadcast in one of the unscheduled time broadcast periods. Of course everyone can get the repeat map broadcast. At the present time, the military gathers information on 'missed maps', (more accurately described as missed required maps) and map quality. The loss of a map at a base that does not need it may be the result of a network failure, but since there is no base operational impact, the loss is not reported, in most cases not even noticed.

The maps from the Weather Central traverse the facilities of several commercial companies while in the CONUS, transit undersea cables and foreign

telephone plants, and may travel for an extended time in the Defense Communication System. The tail portion of the circuit may be provided by either DCS or foreign telephone plants. Anyone who has ever tried to measure and stabilize circuit performance parameters in such a conglomerate structure will understand the complexity. The absence of adequate orderwires throughout the DCS and the lack of interconnections of the existing DOD orderwires with common carriers and PT & T companies assures that all trouble corrections are slow and tedious.

The quality of the map is graded on a three level standard -- good, marginal, or bad -- a missed map if needed, may also be noted. The map grading responsibility is assigned to the user in an attempt to achieve objectivity by having the rating given by someone other than the network operator. This approach sounds reasonable, but in practice does not work. The rater may be a friend of the communicator or at the least a work mate, and so he does not want to cause trouble. In any event, the quality reports are misleading at best, and frequently useless. Figure 5-2 shows the results of 3 specific days of a special 3 month performance assessment study conducted to define the precise quality of the weather maps. The circles code the quality of the maps at several key locations after a central HQ precise grading had been applied. A is good, C is marginal, F is unusable. Without exception, all of the sites receiving maps that were graded less than A gave as the reason one of the following:

1. The backbone structure was bad.
2. The map was bad as sent.
3. The grading criteria cannot be met.

As is evident, all maps on these 3 days were sent A quality since each received a correct A rating at least at one site near the end of the broadcast channel. Most stations received at least one A grade map, so that a strict grade A standard could have been met on all days had all elements of the network been peaked. The broadband portion of the backbone structure obviously was not the fault since Athens, Greece, got all A maps. Yet all of the managers blamed some one else for their poor maps. The map analysis of all European sites for this full three month test compared user grading with a precise centrally conducted evaluation. It substantiated that 82% of the maps were marginal or unusable. Only 18% met the operational need. See Figure 5-3. This unreliability of self-evaluation has been proven in every scientific study known to the author, not only on technical matters but across the spectrum of human endeavors. Self-evaluation can never be used for any assessment or control.

Message traffic control in the normal sense is not meaningful in networks where all messages are broadcast and can be received at all end locations over a hard-wired-fixed-network. Only the input need be subject to control.

The portrayal of weatherfax map quality for managers in a manner such as shown in Fig. 5-2 does high lights problems except it is not in real time presently. As such it is of limited value and the quality must be centrally assessed for accuracy.

The operational problems with this network have fallen into two categories - poor map quality and missed maps. In other similar broadcast

EUROPEAN FACSIMILE MAP ANALYSIS
FOR
9 SPECIFIC RADIO DAYS

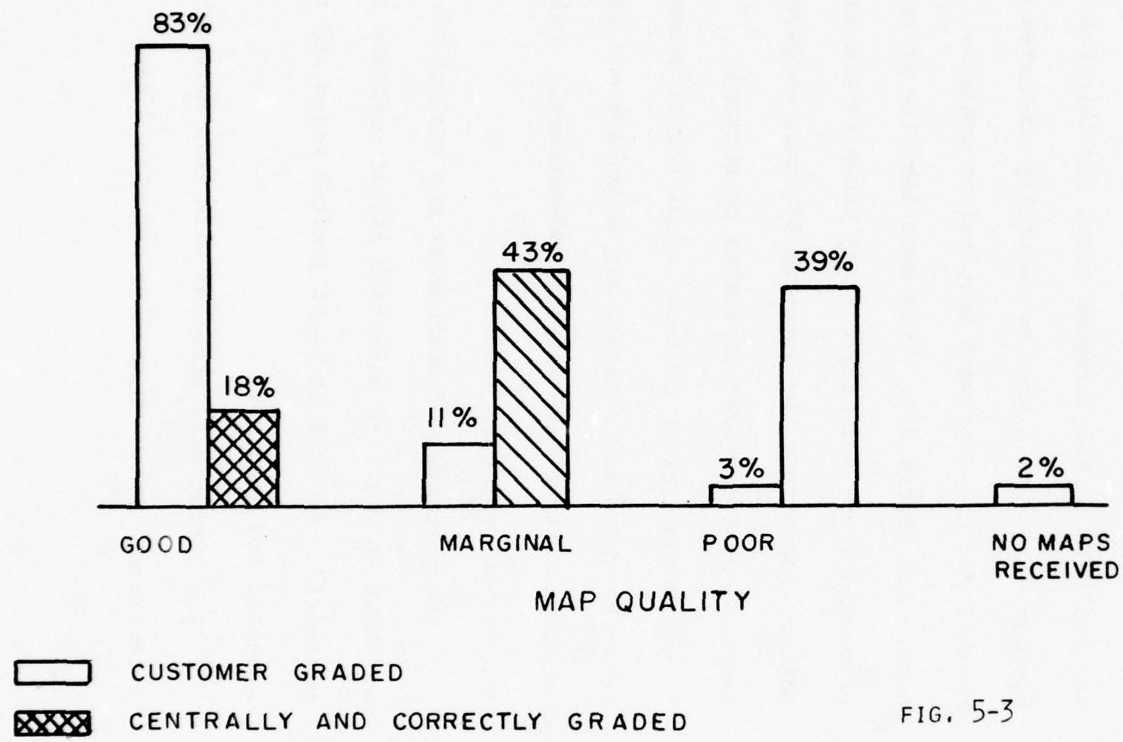


FIG. 5-3

nets, the problems could be poor quality of voice or message traffic or incomplete, garbled or missed messages.

After some testing and analysis it was proved that there was a bit of truth to the accusation that some maps were degraded in transit. This degradation, however, came predominantly 'on base' or in some peripheral device such as an amplifier or line conditioner at or near the terminal, and not in the broadband portion. After a thorough examination, inadequate, or non-existent terminal adjustment, and poor maintenance of the supportive devices was the prime culprit. There were ameliorating conditions that impeded effective maintenance such as no test equipment, poor alignment instructions, etc., but the fact was clear, that the network hardware was not fully operational.

Based upon several special assessment results, equipment maintenance studies and network operational evaluations, the following conceptual performance assessment and control mechanism is needed. While the details are described for the weather graphic net, the SYPAC approach is general and will apply to all broadcast networks with minor adaptions.

b. Performance Assessment

<u>Transmitter</u>. The transmitted maps, on occasions, are less than adequate. Hand-drawn markings are made with felt tip pens of such color that they are not transmitted as a clear-cut image. However, there are maps that are less than ideal, that have to be sent for operational or other reasons; but subscribers now do not know which maps fit this

category, so they may grade the map poor and wonder what is wrong, or blame the backbone structure. The most prevalent problem, however, at the transmit site is that the transmitter hardware is not operating correctly. The levels may be off, the dynamic range of signals may be improper, noise may be inadvertently added to the signal, the distortion may be high, or some interface box to the backbone structure may be operated or maintained incorrectly. There are times when all transmissions cannot be perfect, so a special symbol should be affixed to the map to let all subscribers know that an inferior quality map was sent from the transmit source. Thus, reception of a poor map will initiate no worry or fruitless hardware fix-it action. This point is important, since even infrequent attempts to isolate network problems when none exist leads to the "wolf-alarm" reaction and will dull sensitivity to real problems.

The transmitter site must have full-time monitoring of the signal as it leaves the site, and also after it has traversed all interfacing boxes. The present monitor in the case of weather maps is a standard field terminal floating full time across the transmitted signal. The maps thus recorded purport to show the quality. In practice, the monitoring terminals degrade just as all the other field weathergraphic terminals and for the same reasons, and the quality indications are less reliable than the transmitter itself. Thus, the monitor is of little use practically, and most degradations of the transmitter go undetected. Monitors more reliable than the transmitter obviously are mandatory.

In SYPAC the monitor need not reproduce the full map. There are other

approaches that are more useful, more informative, and can be evaluated automatically. Parameters such as levels of the black and white map signals, width of standard lines in a test pattern, etc., can be sensed and can be alarmed to alert the transmitter site personnel immediately upon threshold penetrations. These parameters displayed on oscilloscopes in the field have already proved their usefulness and validity.

Terminals. The terminals spread worldwide are subject to continual degradation due to aging and wear and tear of electronic and mechanical components. Alignment and adjustment are a frequently recurring and tedious need, if the receivers are to produce good maps. The original terminals were provided with no test equipment and no test pattern generator. It took an extraordinary maintainer to align the terminal with locally available test instruments. As a result, most terminals were in marginal to poor condition. Yet local personnel, lacking the measured proof that their hardware was bad, normally attributed the cause of poor maps to the circuits in the backbone structure. 'The problem must be at your end, mate' syndrome -- and local managers showed no initiative and passively accepted the excuses.

Of particular interest is the fact that broadcast network terminals are receive only. Other type networks use both a send and a receive (duplex) box. Most maintenance men have learned some rudimentary 'loop back' test techniques -- that is, the transmit device can be used as a signal source for testing and trouble shooting the receiver, or vice versa. A broadcast network receiver terminal cannot use this technique, thus a test pattern

generator or signal source is mandatory, and should have been anticipated from the beginning. A test pattern generator was subsequently procured and provided by HQ/AFCS so that it was possible for the maintainer to performance assess his terminal, to achieve proper terminal alignment, and to verify premium performance. Terminals, however, still remain the prime cause of degraded maps.

Any effective network performance assessment and control concept must incorporate a valid and rapid method for assessing the performance of all terminals. Further the concept must contain provisions to trouble shoot and fault isolate all performance degradations of the terminal, the base, the tail and circuitry from the serving tech control.

Recently the Air Force completed the production buy of a new digital weather fax transmitter and terminals. This new digital network will use the identical circuits and will be geographically the same as the present one. The approach for monitoring the key elements at the transmitter site will be identical to that just described above. The terminal, however, is significantly changed and will provide a device that for the first time fits into a SYPAC type integrated network approach.

The circuit parameters tests shown in Fig. 4-4 and 4-5 were made to relate phase jitter and idle channel noise on the actual channels to be used for this new digifax net. The new terminal will work marginally at the boundary of the noise and jitter envelope and at all conditions that are less severe. Neither noise nor jitter parameters were of major interest or concern in the analog weather fax world, but now they represent the

limiting performance criteria for the digifax terminal.

This terminal was designed under requirements to correct the above discussed electro-mechanical terminal faults. The terminal incorporates a special internal test signal source that can be connected to the receiver position through a circuit that simulated line conditioning and adds noise. The terminal thus stressed, is assessed and a realistic performance margin ascertained. This is not the simple DC to DC loopback commonly provided by cheap terminals. The self test accomplished by the weatherfax built in mechanism is fast and precise. A drop of 2 to 4 dB in the performance margin is clearly evident and shows that maintenance is required on the terminal.

During the development of this terminal, it became necessary to add a forward-acting error corrector (FEC) in order to make the terminal function acceptably in the real world as shown by the Fig. 4-4 and 4-5 test data. This error correcting format is applied at the transmitter and is decoded at the terminal. Integral to the operation of the error corrector is, obviously, the ability to detect violations of certain criteria upon which the correcting code is based and to apply appropriate actions to correct the detected errors. AFCS required that this error corrected pulse be brought out to a test point. This test point can be used to trigger a bit error rate counter or for other test use. This test point also is brought out to a light emitting diode (LED) which flashes with a preset length blink each time an error is corrected. This gives the local operator and maintainer a quick and ready reference as to when marginal

conditions pertain. By virtue of the scientific principles governing digital devices, this light will not flash until about 3 to 5 dB prior to full disruption of the terminal operation. This is not as large a predictive degradation margin as is desired, but it is available, and it can be used. An in-service assessment capability was not incorporated (as discussed later in this chapter) although all needed basic elements were present in the terminal. There was no inexpensive way to build in a phase jitter simulator. The precise degradation of this terminal is readily measurable by the out-of-service stressed signal check. This information in conjunction with the error corrected light gives the first honest measure of terminal performance assessment evident in the DCS.

Of prime interest, however, is the fact that the test point, used locally for bit error rate counts, will also be remoted to the nearest tech control for use as one of the network inputs in overall network assessment. This terminal is one of the first if not the first to have a design that acknowledged that a terminal is but a part of a total network system complex. Previously, terminals were rarely, if ever, recognized as integral to anything. There needs to be slight additional circuitry in order to give 25 to 30 dB performance margin predictability. Terminals of all networks can benefit from the lessons learned on this terminal.

This advanced network transmitter/terminal was developed prior to ATEC but was fully compatible with it and with the SYPAC concept. Unfortunately, the basic design of the hardware has proved unsatisfactory and the project was killed. Thus the system integration parameters will

never be evaluated in other than the field test configuration.

Network/System Sensing. Even assuming that the transmitter were perfect, and that all receivers were at premium condition, there are still many places in a total network where operations can go amiss. Even though the backbone structure as a whole is within its performance margin, there are thousands of troublesome patch jacks, pads, 'stunt boxes', etc., in the network that on occasions cause trouble. The difficulty, normally will be associated with but one circuit -- and in this discussion it will be assumed that it is the weather fax network. There must be some way to detect degradation, when and wherever it occurs. The built-in performance assessment of the receiver may not be stressed to the alarm point by small deteriorations, or perhaps, the trouble occurs infrequently. Whatever the reason, some method to detect and isolate the trouble must be devised. This all pervasive overview performance assessment is called Network/System Sensing, and is conducted in the tech controls all along the route from the transmitter to all the end receivers.

The circuitry, while rarely the prime cause of network problems, still contributes to degraded map service. Since some of the maps in this network traverse halfway around the world, it is evident that even minor problems anywhere, including supportive and peripheral boxes can accumulate to be a significant total. It would be possible, of course, to to put weather fax terminals in each tech control along this worldwide network so that all tech controls could monitor the map quality, but the new terminals are fairly expensive and the old ones require significant

maintenance attention. Further, as has been proved at most customer terminals, the presence of a map does not assure objective evaluation. There is, however, a simple, effective, and real time approach to net/system performance assessment. The signal will be assessed by SYPAC, using ATEC developed parameters to ascertain such key criteria as: signal black and white level, dynamic range, distortion, signal dropouts, and signaling tone levels. These characteristics of the transmitted signal, if correct, assure a high quality map signal. The equalization can be checked 'in service' by examining the fine line structure of the maps. Absence of line ghosting or thickening is sufficient to prove acceptable line conditioning.

During a recent field trip in the Pacific to evaluate SYPAC net/ system concepts, simple in-service manual measurements were sufficient to locate an improperly adjusted line equalizer, find several poor terminals, and start a search for a signal level problem of 10 dB that was eventually isolated to the transmitter site in the CONUS. All of this was done with no service disruption using conventional test equipment. The total level isolation problem took several days because of lack of suitable orderwires. All these manual measurements are easily made automatically by ATEC and will be done by software by SYPAC.

An example of how the new integrated Network Performance Assessment and Network/System Sensing functions will fuse to perceive and portray the complete operational picture is described below. See Fig. 5-4. If receiver 1 were having problems as indicated by a flashing self-performance

THE BACKBONE STRUCTURE WITH BROADCAST NET TRAVERSING

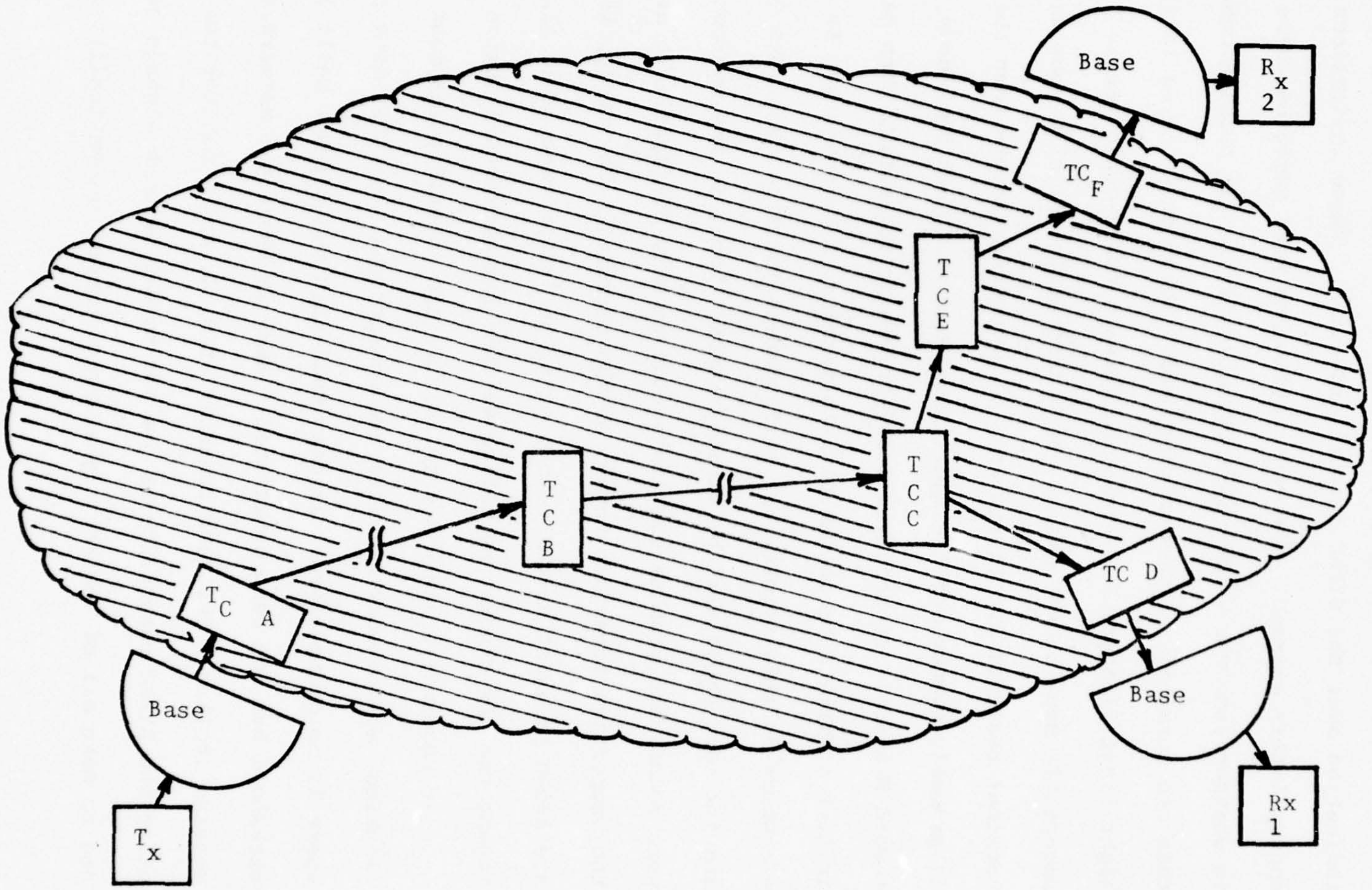


Fig. 5-4

light on the terminal, tech controls C and D would be receiving a similar indication over the SYPAC network orderwire. These indications would be appropriately alarmed. The basic system/network question to be answered is whether receiver 1 only is in trouble, or is the problem common to more than one terminal. Remember this fault isolation is being initiated when the light first flashes, but while the forward error corrector is still providing acceptable maps to the users. Tech control C will also know the status of terminal receiver 2. If it, too, is producing flashes then the problem is probably common and the fault isolation will look back down the structure toward B and A. If receiver 2 is performing correctly, then hardware in tech control C or on the path to terminal 1 is suspect. As discussed elsewhere in this report, the performance status of the links from C to D and the base cable will be already known. Thus, if the backbone structure were sound, the problem must be unique to only the facsimile circuit itself, the supportive interface boxes, or the terminal. Obviously, if troubles are known to exist on the C to D path, or in the base cable plant that impact the fax circuit no unique weather fax corrective action need be taken.

If receiver 1 and 2 are in service and no self assessment lights are blinking, all network services are operational, but this does not mean that there is no degradation. It does mean that the network built in assessment threshold has not been penetrated. Here is where the Network/System sensing applies. The tech controls at B, C, and E monitor the signals using the SYPAC capability to use the normal network signals as 'test tones' and to make all of the key signal measurements automatically, with printout

of the results. This will assess and isolate signal degradations long before the terminal light threshold is reached. If there were any troubles of sufficient magnitude to be of interest to the weatherfax network, the SYPAC signal sensing would pick it up. It tech control C were to find some signal degradation, even though no receiver had yet been affected, he would query tech control B to see whether the problem was evident there also. If not, the fault isolation between B and C would be initiated. If the problem is evident at B, tech control B would assume responsibility for the trouble and repeat the step one major node closer to the transmitter. This thought explains why major node to major node voice and data orderwire channels are absolutely mandatory. In some very wide flung nets, the time to ripple domino like through the entire extent of the circuitry may be undesirable. A quick check at the overseas entry point to ascertain whether the problem is inside or outside the overseas area would be desirable. There are no more than 4 or 5 major nodes required to cover the farthest reaches of Europe, thus quickly the problem can be turned over to the two major node tech controls that straddle the problem for link isolation. In general, the time factor will not be nearly so important under SYPAC as it is now. Trouble shooting today normally starts only after the network has failed. Under SYPAC the isolation of minor degradations will be initiated while acceptable customer service still is being provided.

The weather facsimile network is typical of many in that it uses normal signals, control tones, and special signals of known signature and characteristics. Also, there are periods of no signals. Thus an automated

SYPAC structure can easily be programmed to assess the normal signals, tones and special signals to evaluate their quality and suitability. Of equal importance when no signal is present, SYPAC can also assess the idle channel noise, impulse noise, etc., just as is accomplished for backbone assessment. These circuit characteristic measurements have been demonstrated by the ATEC hardware. In the case of the example weather fax network all circuit measurements are one way - as is the network - from Offutt AFB, Nebraska, to the sensing tech control. It is straight forward to establish circuit performance criteria appropriate to that site and to assess the channel. Software capability is all that is required to decide when signal parameters or tones are not present, and so change the signal evaluation criteria to channel parameters. If any channel parameter degrades passed a threshold, the tech control will start fault isolation.

c. Network Control

Network control for a broadcast net is somewhat limited since the number of actions possible are constrained by the simple structure. However, the creation of a Network Control (NC) where pertinent data can be gathered and analyzed is a mandatory action. Under SYPAC, status and the performance margin of all of the terminals will be known, and this information will already be in one or more tech controls for first level assessment and control action. The next step of course is to centrally gather the performance assessment and status data at a network control point. In the case of the weather fax network, there might be three

subnet area control points including one in Europe, one in the Pacific, and one in the CONUS. There three subnet control points would handle all actions for their area of concern. The 'Region/Sector' might also be used as a subnet manager and refer only major problems to the Area control point for resolution. In the case of weather fax the Air Force or DCA could act as the network control for an Area. To accomplish the needed data interchange, a network orderwire will be required. The lowest level data flow will be from the terminals to the first serving tech control. This tech control will forward the terminal self assessment (in the weather fax case, the blinking light information) to the major node and to Sector where it will be processed. Thus concerned major node tech controls will have the necessary information directly, or sent from Sector to initiate trouble isolation, if the backbone structure seems implicated. The full area status will be gathered at the area subnet central. The Net Control actions might include requesting DCA for reroute in cases of extended backbone or circuit troubles. It could include release of communication traffic to another functional terminal with appropriate instructions on how the information is to be relayed to the defective or isolated terminal. In coordination with the Network Control the transmissions could be controlled and critical data could be to some degree coordinated for periods when the net was acceptable or at least passable to the critical customers. Repeat transmissions would be held until the path to the requiring customer was workable, etc. Network managers would be stationed at each of the area controls to observe all status and trends of various types.

d. Net Orderwire

The network orderwire structure must pass through the serving tech control to all concerned major nodes, to the Sector, and to the subnet area control. The data rate is not high, but the orderwire must accommodate the real time status reporting of terminals, performance margins quantitatively perhaps by exception and be able to handle some limited narrative traffic. In the case of the weather fax network, the terminal can accept any graphic data including narrative if properly generated, so communications downward to the end locations is possible. More will be covered on the orderwire concept in a later orderwire section.

e. Summary

An effective network performance assessment and control concept for a broadcast network consists of providing: accurate monitoring of the transmit device using appropriate key performance parameters; proper in-service self performance assessment of the terminal including performance margin; remoting the in-service performance assessment to appropriate tech controls and to the network control hierarchy assessing the normal network signals in-service; and providing needed orderwires to permit integrated network actions and coordinated activities among the major nodes of the DCS.

3. Dedicated Two Way Network

a. Network Discussion

The dedicated two way network is the normal class of communication

net used for command and control. The community of interest is among a limited group of users. The fact that a dedicated net can be justified is reason to presume that the network is important and warrants premium operation and that the communications are sensitive to time of net processing because of the perishability or the relationship of the data to national survival. This should draw increased management attention to this class of network. The dedicated nets have minimum complexity and variability and the basic structure is easy to understand. As a result, two way dedicated nets are easier to assess and control than switched networks, and because of the duplex nature are normally easier than the broadcast nets.

The dedicated network may cover a very limited geographical area or may be widely dispersed. The prime function of the network, however, is unaffected by the geography and is to provide communications among a relatively few locations or people. The data rates may be high or low, the volume of traffic may be large or small, and the sophistication of the network may be great or slight. The fact, however, that a dedicated network exists, presupposes a high criticality in these times of extreme fund pinch, so these nets have more demanding requirements than can be met by switched networks.

Examples of dedicated two way networks are numerous. Most of the national "hot line" alerting nets are of this type as are many intelligence reporting structures. In civilian life, many of the communication nets for industrial organizations are dedicated. The ARPA net was a dedicated net among high data rate computer users. Fig. 5-5 is a portrayal of a

TWO WAY DEDICATED NETWORK

COMMAND ALERTING NETWORK

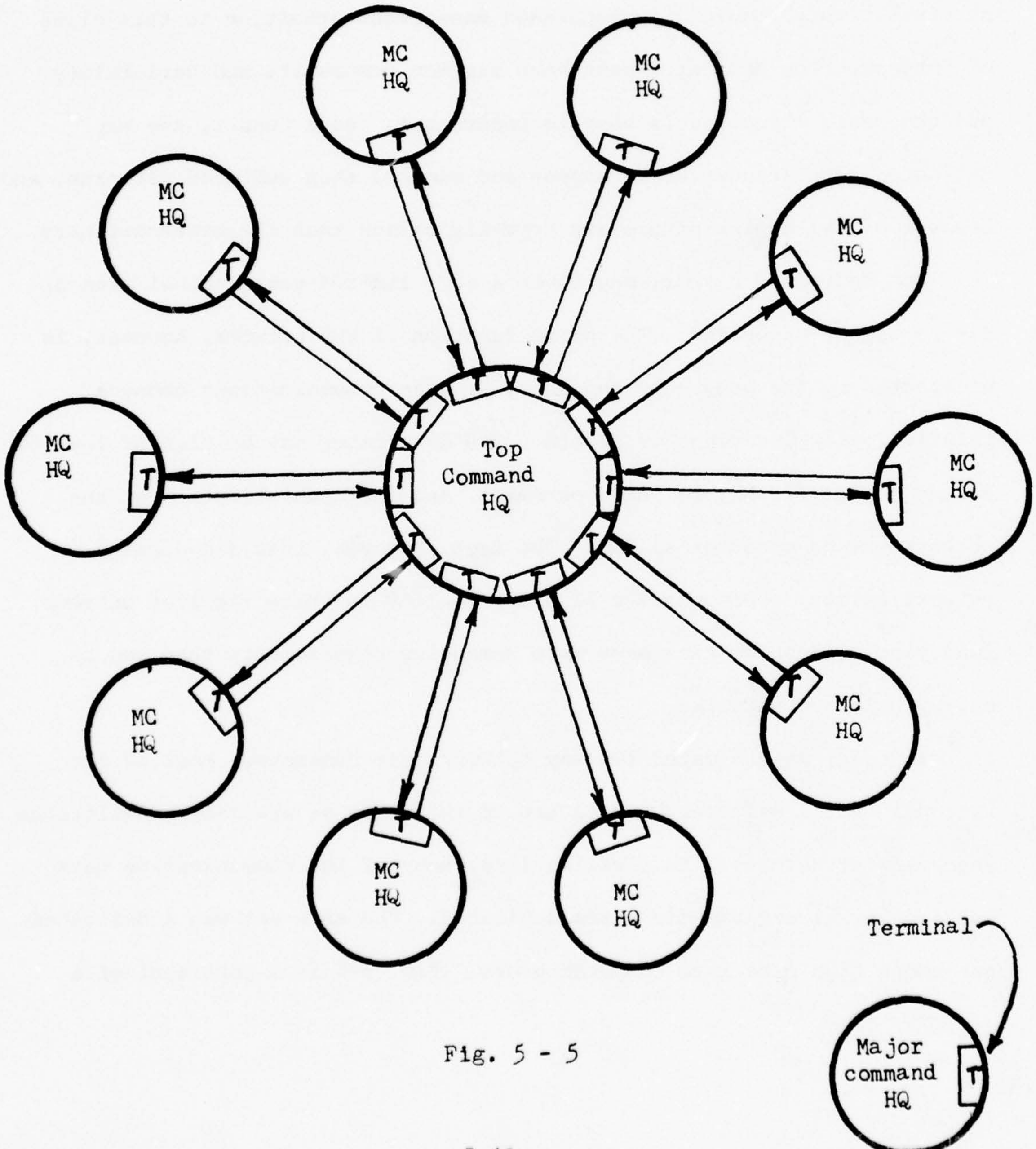


Fig. 5 - 5

typical dedicated two way network used for command alerting. The multiplicity of terminals in the NMCC could be replaced with one large entity, but functionally the portrayal would remain unchanged.

The communication flow in these networks is highly structured and in most examples follows a completely preset pattern. Often there is a central control node with all other subscribers classed as subordinate terminals, although such a Christmas tree form is not mandatory.

Unsophisticated network checking of two way dedicated nets is relatively easy if the sheer size of the total structure does not preclude such testing. Some networks now place test calls periodically from the major node to each terminal or among the appropriate users who acknowledge call reception. This gives a periodic go/no-go status. If the period is frequent, the assurance of network viability can be good. In few nets, however, is there any attempt to measure how well the communications are received. Where data transfer is the network mode, and that is increasingly likely, a precise quality criteria is mandatory. A go test, even if error free, assures only that the minimum performance margin was exceeded by 3 to 5 dB. A further degradation of 5 dB could completely disrupt all communications over the path. In the case of pure voice communications, a precise numerical indicator may not be needed, but quantative data must be gathered to assure that the maintenance of all of the hardware is proper and that the performance margin is at least acceptable, and not degrading.

Many important military networks of the two way dedicated type, traverse several USA commercial companies and may also transit several

military structures. Transmissions for that portion of the net that goes overseas will serially pass through undersea cables, foreign telephone plants, the DCS, and/or perhaps commercial or military satellite links. In other networks, ground to air links may be involved. These communication assemblies are easy but tedious to assess in a go/no-go manner, but when the result is no-go, the fault isolation needed to identify the fault location is nearly always very involved and time consuming. Nevertheless, such fault location must be completed, at least to some degree in order to even bypass the faulty portion. The problem is normally that the particular path of interest is permitted to degrade, with managers lulled to complacency by the routine 'loud and clear' response to the requests for checks. When a no-go response occurs, then managers awaken, maintenance men react and fault isolation is finally undertaken. Designers and operators attempt to ameliorate these problems several ways. The most straight forward, the most effective, and the most expensive, is to duplicate all of elements of the network. Thus, when trouble is encountered, it is possible to use parallel routing, duplicate hardware, in multiple permutations until some combination works.

This class of solution is slow and dependent upon being able quickly and accurately to detect and isolate the failed element. With the advent of more sophisticated electronic terminals, the difficulty of detecting a failure became much greater and exceeds the capability of most personnel, and the speed of correction is inimical to modern high speed network operations. An entirely new approach is required.

All well designed large assemblies of equipment have an error budget. Each device is apportioned its fair share of the total, in order to meet some overall total system error goal. A communication structure should be designed the same way. In a data network the backbone structure is designed to provide a signal to noise of about 34 dB to the average terminal. The average terminal is designed to operate error free at about 24 dB signal to noise. These is a 10 dB network/system degradation margin. It is obvious that the complexity of keeping a multi-link backbone structure at 'like new' is more complex than keeping a terminal at premium alignment, yet presently 5 dB is the accepted degradation margin for the terminal. From Chapter IV, recall that a radio link goes amber at 5 dB degradation. Field measurements by the author have shown that the average terminal is about 7 dB degraded with many much worse, yet managers invariably blame the circuits whenever the network performance becomes marginal or fails.

It is difficult for managers and even for most communicators to understand that a modem, a terminal, or any device that is providing low error rate service may in fact be severely degraded. The consideration that these personnel fail to grasp is that many terminals and all digital terminals are 'brittle'. That is they show few overt signs of stress until they abruptly fail. In practice, the performance of most worldwide networks is marginal with little if any performance margin remaining. The 5 dB degradation in the backbone plus 7 dB in the terminal exceeds the 10 dB error allowance for long high speed data circuits, and in fact this

marginality can be observed on the channel pack trunks in the DCS. At peak traffic hours, every day, the alarms trigger repeatedly, the error rate goes up, ARQ's increase even though the measured noise levels have increased only a few dB. Clearly a better sensing and control mechanism is required to restore the 'like new' performance margins.

b. Network Assessment

Personnel who manage networks and most tech controllers are unaware that there are capabilities already incorporated in existing nets that are the basis for network assessment. These capabilities are very important and support the creation of an in-service real time performance assessment capability for networks from a point remote from any terminal of that network. This sensing is done by bridging the circuit at any intervening tech control and observing the signal and certain unique features that the signal exhibits.

Signal Derived Information. The following discussion describes the approach and illustrates the results obtained using some existing field hardware. The network sensing was done both manually, and also automatically using ATEC. The particular example was not taken from a dedicated two-way network, but rather from a portion of Autodin. This example is used for convenience, but much other data exists to substantiate this concept. The signals travelling among the switches -- switches here are considered terminals -- and their appearance in tech control is exactly like a dedicated two-way net so the parallelism is appropriate, and the principles derived apply to two way dedicated - as well as all other - networks.

These Autodin signals have a number of distinctive features that are of direct interest to the SYPAC concept. The modems that impress the signal from the switch on the circuit are synchronous and use an 1800 cycle tone to achieve set with the remote modem. When the dedicated portion of the network is operating normally, no 1800 tone appears. If the net is disturbed and has to repeat blocks of information to assure parity, periodically the modems resync and the 1800 cycle tone appears for a short time. A simple tone detector can immediately ascertain that a reset has occurred. Frequent resets are an absolute indication that a network problem exists. This reset mechanism is visually observable by watching the display of an oscilloscope bridged across the circuit. This network sensing of trouble is not used either at the switch or the intervening tech controls. Several years ago, a demonstration of this midpoint tech control in-service, non-disturbing assessment was being given to a DCA and a NSA senior communication manager. The 1800 tone resets were rather frequent between two switches and while the demonstration was going on became even more frequent. The author predicted net failure shortly. Both managers were sure that personnel at both switches must be well aware of the obvious problem. The author assured them that this was not likely. A telephone call to both switches disclosed that neither was aware of any difficulty. The net failed in less than 30 minutes. Then, and only then did fault isolation begin. Obviously, the 1800 cycle tone is a useful mechanism to assess network performance anywhere along the circuit.

There are many other capabilities that provide much additional

information of value in network sensing. For example, an oscilloscope bridged across the AUTODIN interswitch trunks can be made to sync with the transmission rate and display a characteristic pattern. The Fig. 5-6 photograph is the output pattern of a good modem taken at the entry tech control. The pattern has little jitter, the line width is narrow, or as a tech controller views it, "The eye pattern is open," and the basic sinewave shape is easily discernable. Figure 5-7 is the pattern of this modem after it has transited a portion of the backbone structure. There has been considerable distortion. The original transmitted signal had a stable sine wave amplitude while the amplitude of the distorted received signal varied irregularly and widely. The average power level of the signal was the same, within .2dB, although it is not possible to extract this information visually. A skilled observer can get considerable valuable information from this scope display. For example, a distorted signal as a result of poor line conditioning can be differentiated from a signal lightly degraded over a properly conditioned line. However, the oscilloscope presentation generally is not useable by all the tech controllers and they refuse to accept it, but the basic descriptive parameters are there, nonetheless.

When ATEC hardware was available in England, ways to measure these degradation features were specifically sought by the author and found. The change in amplitude peaks is related to a parameter called 'peak to average'. This is not the peak to average ratio (PAR Meter) reading in commercial use based upon an out-of-service special test. Rather it is an

in-service non-customer disturbing assessment made upon the actual signal travelling down the circuit. ATEC measured the 'peak to average' at the output of a properly maintained modem, to be approximately 1.0 dB. See Fig. 5-6. ATEC prints the peak to average measurement as "PA". The average power AV in this case is -13.6 dBmØ. The oscilloscope photograph taken at the same time is attached for comparison. Also portrayed is the energy spectrum of the modem. This display is always available and can be plotted by ATEC upon demand by the tech controller based upon a fast Fourier transform in the ATEC hardware.

Figure 5-7 is the ATEC analysis of the same modem signal after passing through the backbone structure. Again an oscilloscope photo is attached to the ATEC readout for comparison purposes. The PA - peak to average - is nearly 6 dB, the AV - average power - 13.8 dbmØ. The power spectrum is not as smoothly distributed as was the original signal but there is no dramatic change. The photograph of the oscilloscope however clearly shows the degradation. ATEC measured it easily and displayed the PA results suitable for use by an individual of any technical competence level. It can be alarmed.

During one of the ATEC tests, an AUTODIN modem signal from a remote switch measured a peak to average in excess of 6.0 dB. Clearly, something major was wrong. Using ATEC the fault was located at the far end. (In this case the far end really was at fault.) The equalizer was malplaced in the transmit line at the send end. The full explanation was not obtained from the far end for the improper positioning, but the error was located

AUTODIN IN-SERVICE PRINTOUT

```
    AV-13.6 N  Ø49/15Ø3 Ø5Ø
AV-13.6     PA+Ø1.Ø     HD+ØØ.Ø     FL-22.Ø
VU-13.5     PA+Ø1.Ø     M1+ØØ.5     M5+ØØ.2     FR+1751     SW+1164
VU-13.5 PA+Ø1.Ø SW+1164 FR+1751 M5+ØØ.2

SPECTRUM 6--- 5----4----3----2----1----0----1
 Ø1 -44.3********
 Ø2 -38.6***********
 Ø3 -35.Ø*************
 Ø4 -33.5**************
 Ø5 -31.8***************
 Ø6 -29.6****************
 Ø7 -28.7****************
 Ø8 -27.6*****************
 Ø9 -27.6*****************
 1Ø -28.3****************
 11 -26.3*****************
 12 -24.8******************
 13 -25.7******************
 14 -26.8*****************
 15 -25.Ø******************
 16 -24.3******************
 17 -24.3******************
 18 -24.2******************
 19 -25.Ø******************
 2Ø -25.Ø******************
 21 -24.3******************
 22 -25.Ø******************
 23 -25.9******************
 24 -26.6*****************
 25 -26.7*****************
 26 -26.6*****************
 27 -26.7*****************
 28 -28.1****************
 29 -29.Ø****************
 3Ø -29.1****************
 31 -29.9****************
 32 -3Ø.8***************
 33 -32.3**************
 34 -35.1*************
 35 -34.9*************
 36 -35.Ø*************
 37 -37.4************
 38 -4Ø.9**********
 39 -42.Ø*********
 4Ø -43.4*********
```

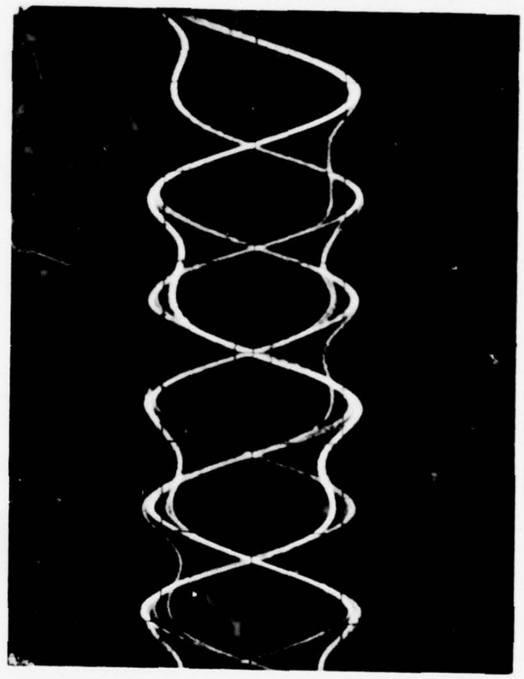


Fig. 5 - 6

```
MI,5Ø,2,3

    AV-13.8 N  Ø49/1531 Ø5Ø
AV-13.8      PA+Ø5.9     HD+ØØ.Ø     FL-12.6
VU-13.7      PA+Ø5.9     MI+Ø1.2     M5+ØØ.5      FR+1858     SW+1148
VU-13.7 PA+25.9 SW+1148 FR+1858 M5+ØØ.5

SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -54.7***
 Ø2 -44.4********
 Ø3 -37.8************
 Ø4 -33.9**************
 Ø5 -3Ø.1***************
 Ø6 -31.Ø***************
 Ø7 -29.9****************
 Ø8 -28.Ø*****************
 Ø9 -27.7*****************
 1Ø -27.7*****************
 11 -28.1****************
 12 -28.5****************
 13 -27.1*****************
 14 -26.Ø******************
 15 -25.2******************
 16 -24.6******************
 17 -26.1*****************
 18 -25.3******************
 19 -24.Ø*******************
 2Ø -25.6******************
 21 -24.6******************
 22 -24.6******************
 23 -25.9******************
 24 -25.5******************
 25 -26.1*****************
 26 -25.2******************
 27 -26.3*****************
 28 -28.2****************
 29 -27.6*****************
 3Ø -29.9****************
 31 -3Ø.7***************
 32 -29.6****************
 33 -3Ø.8***************
 34 -33.9**************
 35 -41.5**********
 36 -58.6*
 37 -73.Ø
 38 -78.4
 39 -79.6
 4Ø -8Ø.1
```

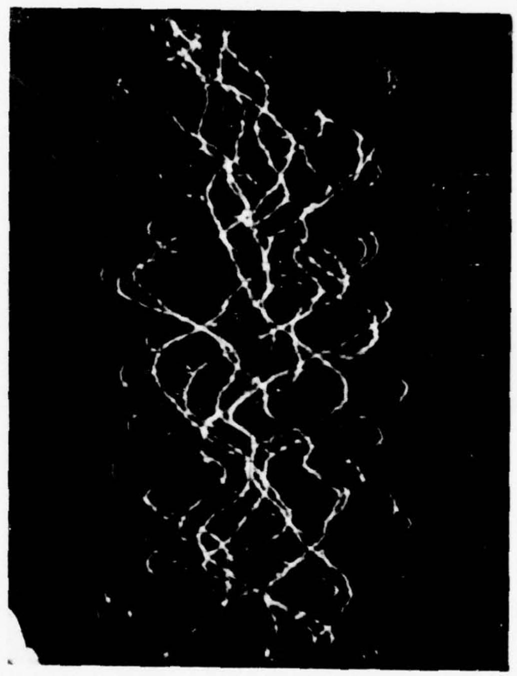


Fig. 5 - 7

and documented during testing. In this example the trouble might have been caused by a mispatch, installation error, or by a maintenance mistake. It was corrected by the maintainer while troubleshooting at our direction and without his recognizing either the problem or the corrective action. He then reported to DCA, "cleared while checking". This example demonstrates the difficulty in getting a valid reason for outage (RFO). Using an ATEC application of the SYPAC concept, the real fault was identified. In the future, analysis of SYPAC derived RFO's can lead to effective product improvement and network upgrades because the RFO data will be correct. Parenthetically, the tech controller took more than two hours to try and isolate this problem using DCS orderwires and had not yet finished due to continual interruptions. The author authorized a commercial long distance call to the remote point, and the problem was resolved quickly.

One of the spare local modems was tested and its peak to average was 2.0 dB vs. the 1.0 dB standard. Maintenance fixed the problem, once it was called to their attention -- once they knew "there was a problem."

Another local modem had a high peak to average signal. Troubleshooting using ATEC as the degradation monitor found a bad cable to shield isolator solder joint in the cable pair from the modem to the tech control. The isolator is a "Tempest" filter. Resoldering the joint restored the correct modem PA reading. None of these system problems would have been found by using the box oriented 'logistic' tech order approach.

A series of tests was run to prove that the Peak to Average - PA -

readings were related to modem failure modes. A pair of modems were looped back through a line distortion simulator. The simulator was adjusted to portray increasingly long unequalized circuits -- providing poorer and poorer characteristics. The modem performance was plotted against PA readings as measured by ATEC. The modem ceased operation at a PA of 7.0 dB, as the circuit delay distortion increased. Next, the simulator was adjusted to put unusual humps, both positive and negative at the ends and later in the middle of the bandpass. The modem ignored all these unusual activities until the PA readings rose to about 7.0 dB, where it always failed. Regardless of the manner of stressing, the modem always failed at about 7.0 dB. Obviously, then, peak to average is a valid operational assessment parameter for <u>this</u> modem. The signal to noise performance of this modem is quite good, so is not normally the cause for failure.

More importantly, the stable performance of the modem in relationship to the peak to average reading, permits the establishment of management performance margin thresholds. Fig. 5-8 is useful in visualizing the results of these performance margin tests. It is seen that the normal modem operating point in the DCS is only a few dB away from failure. The circuit can degrade the signal no more than 2 or 3 dB before failure of the net. If the modem itself degrades, this performance margin is even less, although not necessarily linearly.

The salient point however is not that these checks identify defects with the circuit or modem. In normal out of service testing on almost any electronic device or assembly, the approach is to insert a test tone and

MODEM PERFORMANCE MARGIN

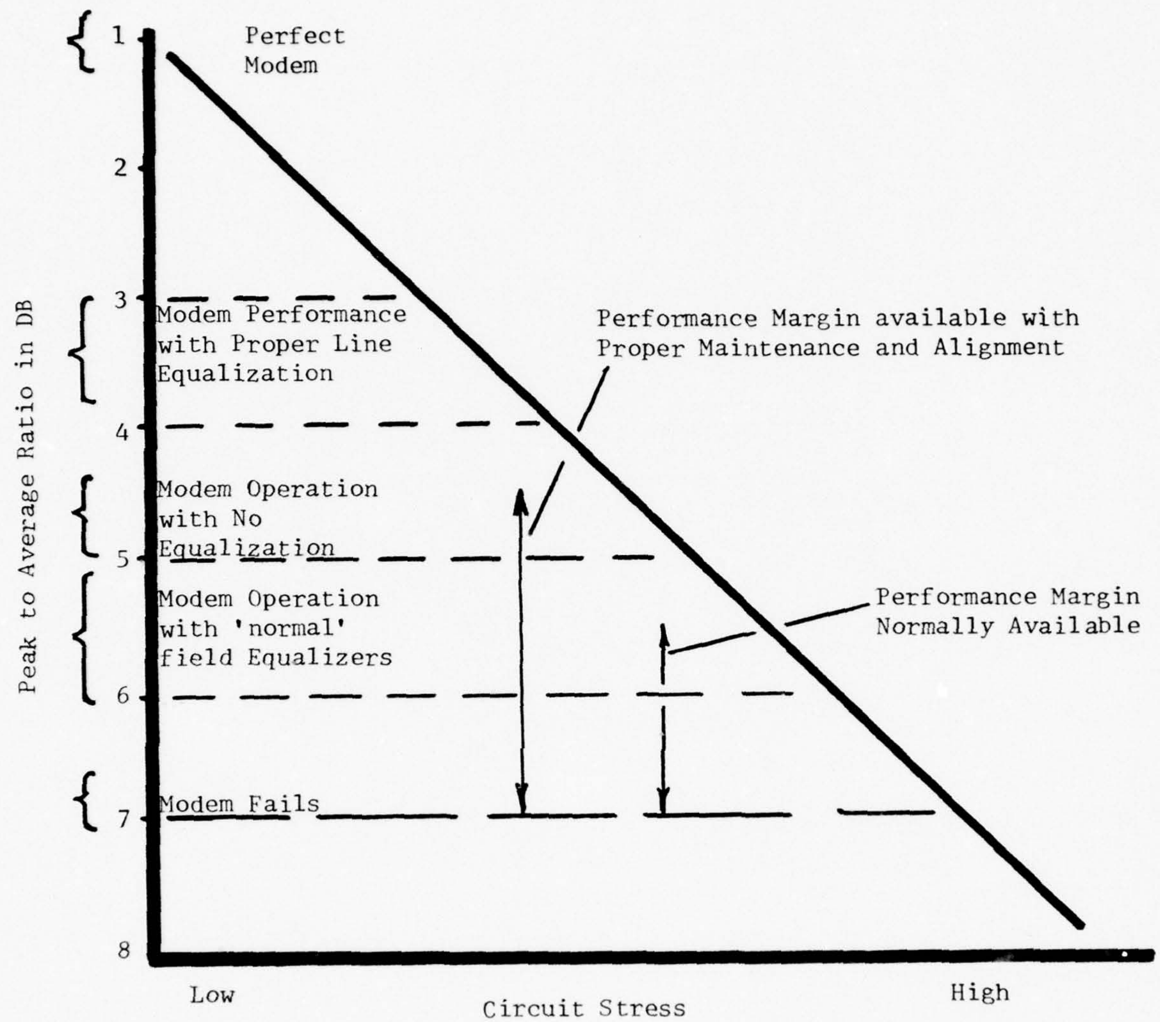


Fig. 5-8

then observe the distortions and degradations as the tone progresses through the assembly. With SYPAC there is no requirement that this signal be the normally used 1000 Hz tone. This tone is used because many test instruments are keyed uniquely to 1000 Hz. However once SYPAC (or ATEC) automated assessment is fielded, there is little reason to continue use of 1000 Hz or need to continue most out-of-service signal tracing. The signals already progressing through the DCS are adequate. The only requirement being that the characterization of the signals must be known. The above discussion on the Autodin signal was but one example where the author was able to fully define the key operationl parameters using the fast Fourier transform signature approach. A point of note also, for those who believe the presence of an equalizer in a circuit assures an equalized line. The equalizer at many sites tested, resulted in worse performance due to malalignment than no equalizer at all. There is a version of a Stelma equalizer, widely installed in AUTODIN in the DCS that can be adjusted to flat phase and amplitude response 600 to 2800 cycles. However it introduces a small but abrupt phase change just below 600 cycles, and a large and disruptive phase change just above 2800 cycles. Most other equalizers cover at least 200 cycles more on the lower and 400 cycles greater on the high end, for measurably better modem performance. The Stelma equalizer never can achieve optimum line equalization and reduces the performance margin of the modem.

An additional point of note is illustrated in Fig. 5-9. This diagram expands the narrative points made several times in the SYPAC report:

CUSTOMERS VIEW OF MODEM PERFORMANCE FOR ONE CLASS OF MODEM

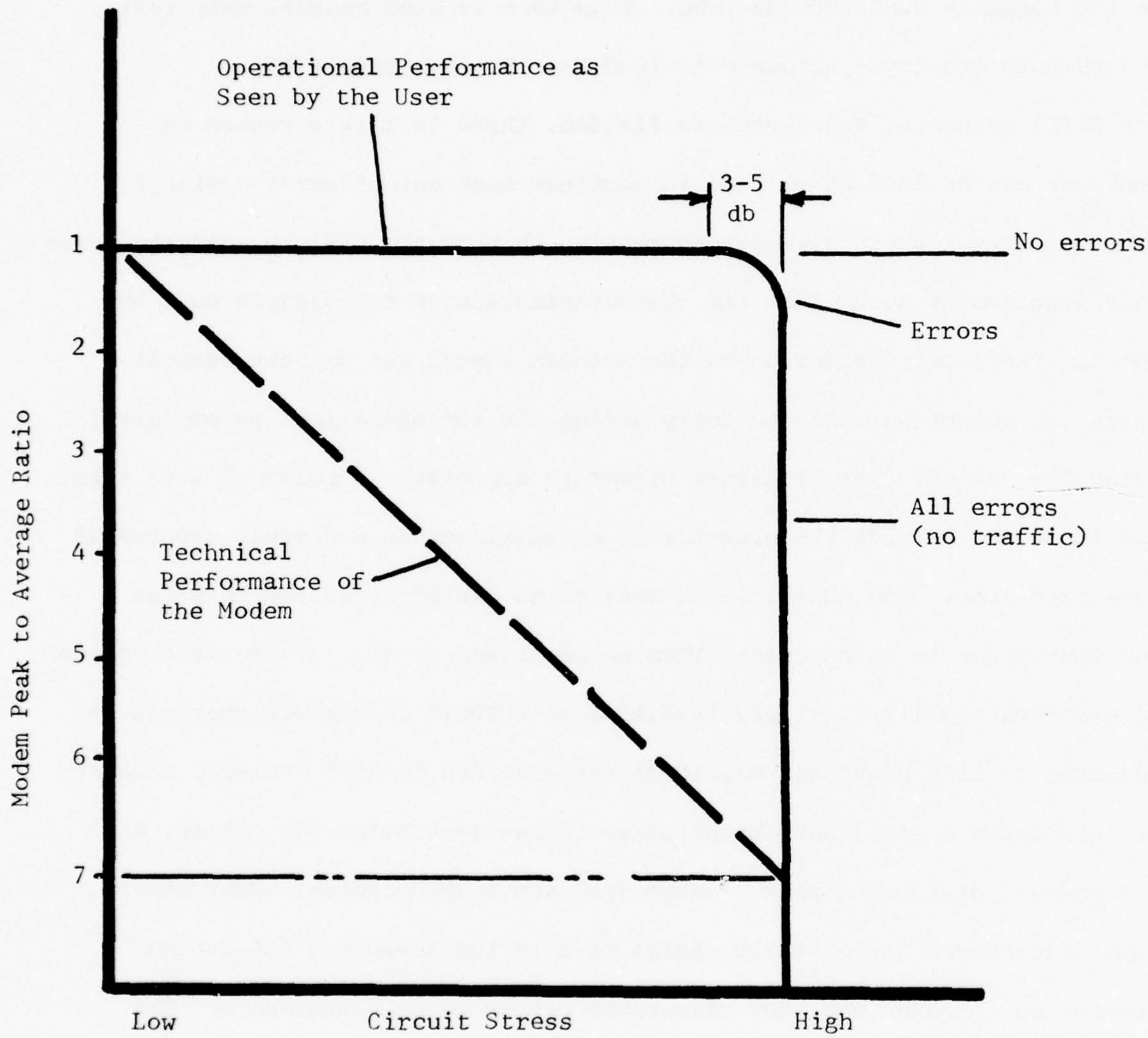


Fig. 5-9

a. modem performance is brittle and failure is abrupt.

b. abrupt modem failure may be good from a customer standpoint but it imposes severe operational problems on the O&M Agency.

Even with fairly high circuit stress or with high circuit or modem non-linearities, the error performance of the modem is quite acceptable until just before complete failure. The customer believes all is well, but suddenly he has no service. The present day communications manager unfortunately shares the same sanguine view and is unhappily surprised at the same time as the user.

In the SYPAC era, or when the ATEC capabilities are available, both the circuit parameters and the modem signatures can be assessed with precision. Then the communication manager can see the real network status and can act accordingly. The user still will remain blissfully content even when events approach the breakpoint on the performance curve, as long as correction precedes failure.

We have discussed above several of the parameters easily discernible for an Autodin modem. This is not the only modem whose degradation becomes recognizable to an automated machine or to anyone examining the signature. For example, Fig. 5-10 is the readout and signature plot for a new modem. This modem transmits at high speed and has a spectrum much like the 2400 b/s Autodin modem, although there are clearly distinctive differences. Note the tone at 2800 Hz, the slight irregularities over the 400 - 2400 Hz. part of the spectrum, and the peak to average reading of 7.1 db. This signature could be picked out from any other modem in the inventory very quickly

RIXON MODEM SIGNATURE

```
! MI,8,2,3

    AV-19.8 WH Ø56/1332 ØØ8
AV-19.8     PA+Ø7.1     PI-12.2     RI+Ø4.4
VU-18.8     PA+0/7.1    M1+Ø2.6     M5+ØØ.9     FR+2822     SW+1219
VU-18.8 PA+Ø7.1 SW+1219 FR+2822 M5+ØØ.9

SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -62.7
 Ø2 -61.4
 Ø3 -5Ø.7*****
 Ø4 -42.1*********
 Ø5 -37.5************
 Ø6 -34.2*************
 Ø7 -32.7**************
 Ø8 -33.4**************
 Ø9 -32.4**************
 1Ø -31.7***************
 11 -32.2**************
 12 -33.6**************
 13 -32.6**************
 14 -32.1**************
 15 -3Ø.8***************
 16 -29.7****************
 17 -31.4***************
 18 -31.3***************
 19 -31.7***************
 20 -31.5***************
 21 -31.1***************
 22 -32.6**************
 23 -31.Ø***************
 24 -3Ø.2***************
 25 -34.2************
 26 -43.6*********
 27 -33.8*************
 28 -26.2*****************
 29 -29.2****************
 3Ø -49.1******
 31 -62.5
 32 -66.4
 33 -68.2
 34 -7Ø.4
```

Fig. 5 - 10

by automated signature examination of the parameters just mentioned. The ATEC type fast Fourier transform measurements are intended for signature recognition and assessment, among other things.

A spectrum obviously very easy to identify is that of the standard 1200 b/s modem used in the DCS in the Autodin net. Note the two spectrum peaks at 1200 and 2400 Hz. and the relatively smooth shape outside these two peaks. See Fig. 5-11. This figure is as measured at the send end. Were this signature taken a number of hops away, the spectrum would roll off smoothly above 3200 Hz. much as the spectrum now does below 500.

Another example is illustrated in Fig. 5-12. This is the signature of the weather facsimile signal discussed under the previous Broadcast Network section earlier. The signature is easily recognized by ATEC or other automatic sensing. *There is a tone at 1800 and the spectrum* falls off relatively smoothly both above and below. Note also in the print out, NF is 1800 derived from the Fourier spectrum analysis automatically. There is no other signature which gives this print out. The peak to average reading here is 9.2 db, but this is useless in this particular case since the black and white weatherfax map material can produce a peak to average of anywhere between 1 and about 25 db. depending upon the ratio of black to white in the map. The parameters of interest here are PI and I5. The PI gives the level of the black map signal, in this case -7.1 dbmØ. I5 gives the white level of 22.4 dmbØ. This is a dynamic range of 16 db which is correct. The black level is too 'hot'. More will be said later on the recognition and analysis of fast Fourier

```
MI, 82,2,3
   AV-11.7 WL 343/1507 PART/0082
AV-11.7     PA+04.3     PI-07.4     RS+02.9
VU-11.6     PA+04.3     M1+01.1     M5+00.5     FR+1196     SW+0983
VU-11.6 PA+04.3 SW+0983 FR-:196 M5+00.5

SPECTRUM 5----5----4----3----2----1----0----1
 01 -49.1******
 02 -51.3*****
 03 -48.3******
 04 -43.6*********
 05 -40.3**********
 06 -36.5************
 07 -34.8*************
 08 -32.5**************
 09 -30.2***************
 10 -28.2****************
 11 -21.8********************
 12 -16.9**********************
 13 -20.9********************
 14 -24.5******************
 15 -24.5******************
 16 -24.2******************
 17 -23.9*******************
 18 -23.2*******************
 19 -24.1******************
 20 -24.6******************
 21 -25.1******************
 22 -25.4******************
 23 -22.7*******************
 24 -18.2*********************
 25 -23.2*******************
 26 -28.7****************
 27 -31.5***************
 28 -33.4**************
 29 -34.8*************
 30 -35.3*************
 31 -37.7************
 32 -39.6************
 33 -38.9***********
 34 -39.9***********
```

1200 BIT PER SECOND MODEM AT SEND LOCATION

Fig. 5 - 11

WEATHERFAX SIGNATURE AT THE RECEIVE END

```
AH  PI-07.1  FX 226/1325 013
PI-07.1AH  PA+09.2   NF+1800   NC+13.6   AV-16.3   FL-20.7G
I1-30.9    X1-10.8   I5-22.4   FL-20.7   M1+20.0   P1+05.4
VU-14.0    PA+09.2   SW+0232   PR+1794   M5+10.3

SPECTRUM 6----5----4----3----2----1----0----1
 01 -56.3**
 02 -57.3**
 03 -59.5*
 04 -58.2*
 05 -57.3**
 06 -53.0****
 07 -47.7*******
 08 -46.1*******
 09 -42.9*********
 10 -37.5************
 11 -37.8************
 12 -38.5***********
 13 -34.9*************
 14 -30.7***************
 15 -31.3***************
 16 -30.7***************
 17 -22.3*******************
 18 -17.2**********************
 19 -22.3*******************
 20 -30.2***************
 21 -31.2***************
 22 -30.4***************
 23 -34.0*************
 24 -37.8************
 25 -37.2************
 26 -37.4************
 27 -41.1**********
 28 -43.2*********
 29 -43.9*********
 30 -44.7********
 31 -45.1********
 32 -45.6********
 33 -45.7********
 34 -48.3******
```

Fig. 5-12

transform derived signal signatures and of the uses to which such signature recognition can be put in data base validation and other functions. Thus a concept was demonstrated for conducting network performance assessment on an in-service and non-interfering basis, sensed at any point or tech control between the terminals, including measurements taken at either end.

The total system picture, of course, could not emerge from the ATEC measurements made at one point in England by the one ATEC instrument, but a principle was born. During the subsequent tests, the principles were expanded. More will be said of the complete system assessment in a later section, where the manner in which all sensed data is integrated to portray the entire communication system status.

Hardware Derived Information. As was described under the broadcast net discussion, there is an in-service assessment concept already implemented and suitable for SYPAC embodiment. All electronic boxes have, or can have, within them, several points where voltages or currents are related to the operating condition of the device. The digital weather facsimile terminal corrected errors as they occurred, and each error correction was brought to the attention of the outside world in the form of a flashing light or a pulse. This terminal happens to be the only one to date designed and produced to fit directly into the SYPAC approach. However at no expense, the channel packing TDM/Modem presently in use in the DCS also can be wired to fit. This modem already has built-in automatic line equalization and at the request of AFCS, a varying DC voltage that

relates to the stress the modem faces in compensating for signal distortion is brought out to a test point. This voltage indicates the result of modem reaction to the integrated degradations all the way from the transmit terminal to the receive terminal. This commercial Modem uses the voltage through a comparator to flash a red light and ring an alarm when the integrated stress is approaching the modem marginal condition. This voltage should be presented on a meter and to SYPAC. Thus, not only would the status at a given time be known, but more importantly, the trend would be observed to correlate with other observations on other networks and with the backbone structure status.

A most recent commercial modem is just entering the DCS inventory. AFCS ran a few key tests in the field. They found a basic installation oversight remedied several interface mistakes, corrected a basic design error, and located several defective modems. (Parenthetically, all modems tested 'go' in simple loop back.) The remaining modems demonstrated acceptable bit error rate performance, under average circuit conditions. This particular modem has a meter on the front panel that reads 0 to 1 in arbitrary units, -- related to modem stress. A meter reading of 0.2 means less than 10^{-5} bit error rate. At a reading in the vicinity of 0.8 the modem provides an unacceptable error rate and on occasions drop from synchronism with the remote modem. The meter is not precise in that any meter reading can represent a small range of bit error rates depending upon the type of stress imposed, but a usable, in-service self-assessment concept is already incorporated in this modem.

There are other examples. The most advanced one is the digital self-performance assessment principle developed at AFCS for use on a digital backbone radio/link. A later commercial development was an improvement over the original in several ways, but retained the same principles. This concept has been applied to several radios and gives either an analogue voltage or a numerical readout of degradation. It is sensitive and gives more than 30 dB prediction prior to failure. The readout in either voltage or numerical format is entirely suitable for remoting to SYPAC for network and system control.

Thus it is obvious that not only is there a viable concept for terminal or assembly in service self-performance assessment, but it has been reduced to practice and ready for SYPAC in a number of cases. In other examples the extension to fit SYPAC is a very simple matter, since the circuitry is already existant in many devices. Discussions with design engineers and considerable Scope Creek type field testing work has made it obvious that such internal self-assessment generally will be easy to provide -- inexpensively -- assuming that the task is given to the device designer at the start of his design effort.

Internal self performance assessment designed to retrofit as an applique to existing units is normally reasonable, and would be justified for those boxes with a long operational life expectancy. This retrofit action is possible because all components of the older devices are discrete and all voltages and currents are readily available. On later vintage equipment the applique approach will become more difficult since integrated

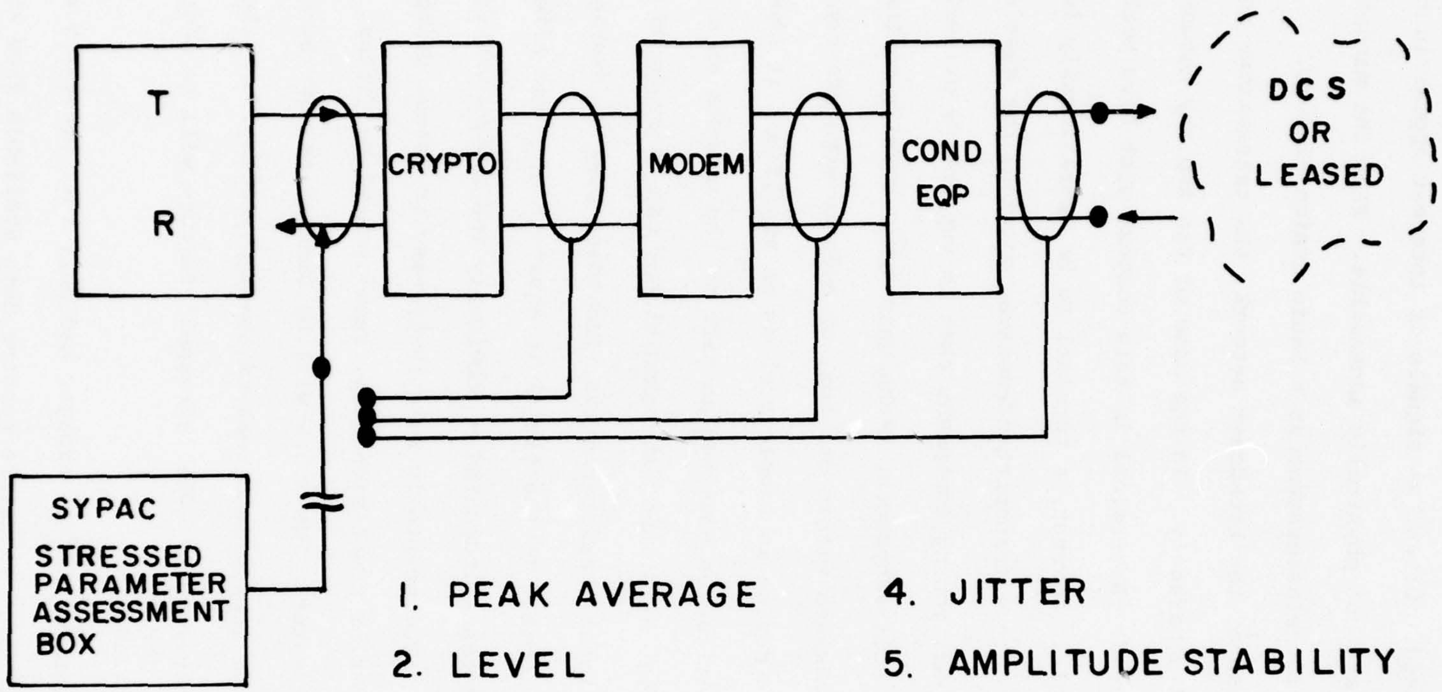
circuits are used. Often the signals of interest appear in the middle of a chip and so are not physically accessible. Thus the mandatory emphasis on self performance assessment as a basic design element.

In the case of the broadcast network, the transmitter and receiver were addressed separately. In the case of the two way network, the word terminal was used. A terminal in this context must have both a transmit and receive role. However, a terminal to be operationally functional may encompass not only a transmitter/receiver portion, but also crypto, modem, and special conditioning equipment that is supportive or serial in the circuit. The self-assessment techniques apply equally to these devices, whether all packaged within one box, or each in separate containers. If the supportive device is simple such as an amplifier, it need not be checked separately, but can be assessed as part of the network as a whole. For example, in Fig. 5-13, the line conditioner can be assessed by comparing the unequalized signal characteristics, including peak to average, to the conditioned signal. If the signal is equal to or worse after processing as most field tests indicated -- obviously the conditioner is poorly adjusted, or defective. The crypto is relatively easy to assess using already provided alarms or reset signature, supplemented by jitter, or other pertinent parameter. The modem will be checked as covered earlier and alarmed for the appropriate peak to average reading, or other signal degradation parameters. The 'stressed' feature will be addressed in a following section.

If the system control manager had only that presently understood in-service midpoint signature sensing data available from ATEC properly

INSERVICE TERMINAL ASSEMBLY CHECKS

(SIGNAL CHARACTERISTICS)



1. PEAK AVERAGE
2. LEVEL
3. WAVE SHAPE
4. JITTER
5. AMPLITUDE STABILITY
6. NETWORK TROUBLE SIGNAL *

FIG. 5-13

analyzed, plus that self-assessment from the network components that is easily provided, he would be in a good position to make technically sound decisions. The ATEC can be educated to do more and more by simple software changes as this added capability is operationally derived.

The described in-service network/system sensing information, combined with the hardware self-performance assessment data would give sufficient knowledge to answer the key SYPAC questions:

Is there a network problem?

Where is the problem?

Is there an adverse trend?

These are the issues that must concern management, and these are the matters that must be answered before any effective management can be attempted.

The SYPAC signature/signal assessment approach was later applied in principle to the Autovon network, to the weather fax net, and then to others. It applied equally well for all of the nets. Further it became clear that the data collected from the several networks was highly synergistic. The applied principles of SYPAC do produce the necessary status data to manage the network hardware and the interconnective portion of the backbone structure.

c. Network Control

The capability to produce information from the internal hardware self-assessment and from the signal derived degradation information collected

throughout the tech controls of the backbone structure must be the basis of network control in the DCS. This data must be assembled and provided to the network controller in near real time so this requires automated electrical means. Real time information flow is required when tracking intermittent conditions, and it is also mandatory to manage rapidly changing military situations. Real time in command and control nets means one minute or less. The gathering of realistic and real time data also has an interesting byproduct, that of cancelling the need for the plethora of manually gathered, hours late, and frequently wrong, reason for outage reports. SYPAC will permit a precise and documented basis for both rapid and long term hardware corrective action and will provide a practical performance picture upon which to base not only control, but management and planning actions. Much planning now is counter-productive.

There are two general classes of control that can be exercised in any network. One class relates to control of all of the hardware elements unique to the network, the other covers the control of communication traffic flow within the net.

The traffic flow in a two way dedicated network is only slightly more complex than that rather trivial flow direction previously discussed in the broadcast network. In the configuration layout shown in Fig. 5-5, any message can go from the center hub to any of the remote terminals, or vice versa. There is no way that anyone can block or impede anyone else. Thus in essence there is little need for traffic control. There are other

configurations for dedicated networks, but all usual ones have one feature in common, -- they are highly structured and non-blocking networks. This does not mean that there will not be some control exercised to clear out traffic just prior to a major hostilities alert, or for some other overriding event, but it means that the control is rarely needed, for traffic flow purposes alone.

In the future it is foreseen that a number of these dedicated nets may be interconnected. In the example of Fig. 5-5, there is another similarly configured net to carry the alert to subordinate HQs of each of the major commands portrayed. Each of these HQs in turn, may have a like net. The communications leaving the top Command Hq, of course, are not normally of suitable form to go to the bottom of the series of Christmas tree networks. However, there may be some kinds of messages that could presumably go past the first Fig. 5-5 portrayed HQ. When this happens, there may be a need for minimum traffic control. There may also be a need for a priority or alerting scheme to assure that all network participants recognize the importance of a communique. The priority scheme, however, cannot be manually implemented because then it is subject to human frailties -- Murphy's Law. The mechanism for control of traffic must integrate with the hardware in such a manner as to force compliance within the network. Any scheme of traffic control that depends upon reception, understanding, and appropriate response by a large group of subscribers is guaranteed to fail somewhere at critical times. The control must be exercised from a central point, and have the control electronically

implemented automatically inside the network devices. The commercial telephone companies have long recognized that hardware control is the only effective manner to control customers. Hardware control is not difficult to do, and requires only the decision by DCA to do so.

The absolute need for mandatory electronic remotely controlled terminals and networks is perhaps not clear at this point in the study. More will be covered specifically in the section under orderwires and satellites.

The control of the hardware of the network is a very active and important function. 100% operational peaking of all network hardware elements does not, in itself, assure 100% network operational suitability, but the reverse is supremely true -- less than 100% hardware acceptability assures less than 100% network capability. Consequently, the attention devoted to hardware performance assessment must be high.

The previous sections have covered several of the types of built-in self-assessment approaches. These principles need to be applied to every major device in the network. Further the results of this self-performance assessment need to be assembled by a reporting structure so that the Net and System Control will always know the status. Once the status is known, the Net Control can decide what needs to be done. Obviously, all technical actions need not, and in fact cannot, be taken centrally, but the decision to approach a problem a particular way, can be. The customer is not a well-educated communicator and does not understand, for example, performance margin. The only quality preservation approach he is likely

to have experienced is with a mechanical device, perhaps his automobile, where quality attention was done by rote, on a given day of the month, not too well, and at high cost. Most customers have been conditioned to do nothing until it breaks. It is cheaper and the mechanic does not break it while testing.

The customer can be directed by the Net Control to substitute or to switch to an alternate terminal or to call for maintenance action. Since these procedures will be started while operational needs are still being met, the time cycle can be more relaxed.

The full details of all possible control actions need not be described in detail, but can be quickly summarized as indicated below:

a. evaluate the status of terminals, network nodes, peripheral hardware, and control corrective action for degrading hardware.

b. observe the conditions of the network circuitry and initiate corrective action in time to preserve network integrity. Direct the repair or altroute in coordination with the backbone controller, or direct a change in data rate of a degrading terminal or other appropriate action.

c. watch traffic flow, military alert status, etc. and control and direct major maintenance, net restructing, or other broadly impacting network action to preserve network operational integrity.

Traffic sensing and control within this class of network is not often a major problem since the input and output elements are relatively easy to control.

The portrayal of network status to managers for this class of network is again rather straightforward, and does not pose a technical problem.

d. Network Orderwire

Most technicians and others who have worked in the field have an experienced based understanding of the need for orderwires. They believe that an orderwire is a voice channel among a number of facilities used now and again when the location of a problem is not clear, or to request another site for assistance in fault isolation. This view is both wrong and not acceptable in a network system sense. SYPAC is conceived to sense and provide enough data to the management structure to permit the attack and resolution of sophisticated and complex problems, including complete failures, major degradations, modest deteriorations and intermittent network or hardware difficulties.

DCA presently directs that network and other orderwires will be provided by use of Autovon. This approach is not acceptable for true network operation and control -- as contrasted with what is done today because of completely inadequate sizing of the existing orderwire structure. The admonition to use Autovon is a simplistic and superficial thought.

In peace time, with little stress on the communication system, an 'immediate' call during the normal working hours has an uninterrupted call period of about 3 to 5 minutes. The author was able personally to check Autovon operation in times of cold war stress in SEA. There, an immediate

call had trouble if it had to traverse more than one or two switches either daytime or night. Obviously Autovon can provide a supplemental capability -- but this capability is generally restricted to those times when it is not needed, when all is well. Equally obvious when things are not going smoothly, when some major portion of a major net is out of service, the availability of Autovon to tech controls will be poor. It is inconceivable that the surviveability of two way dedicated command and control networks is dependent upon a common user structure and with a call precedent lower than the net being served. An Autovon orderwire to assure survival of the command and control networks will be largely inoperative in times of stress.

Under SYPAC the results of the complete self-assessment of all terminal assemblies, the performance assessment of all hardware at the node site, and traffic data and traffic related information, will be passed over a net overhead orderwire to the Net Control. In the case of Fig. 5-5 the net control clearly is the central node. The self performance assessment results should also be provided both the local customer in flashing light or alarm form, so that he also is aware of the condition of his communications. As in the case of any worldwide net, there may be subnet area controls to handle geographical extents such as Europe. This subnet area approach simplifies the coordination with the DCA.

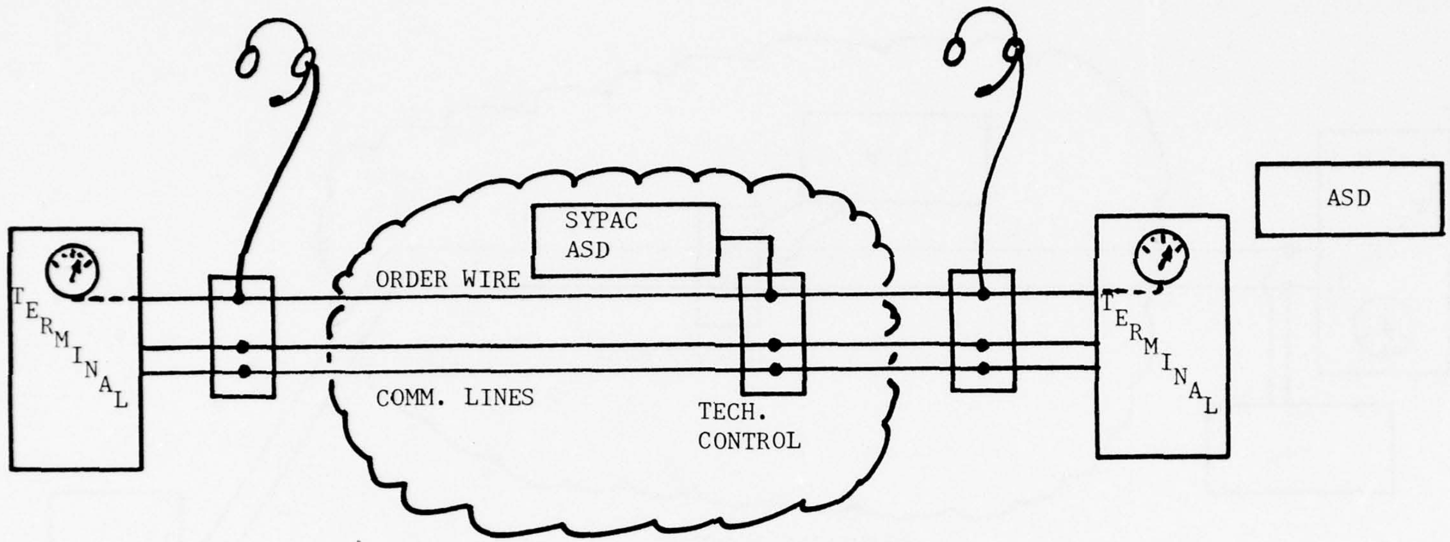
Further in the SYPAC era there will be network data analysis followed by control operations. These control actions will be by automated means. For those reasons covered earlier, and to be expanded in the satellite

net discussion, the control must be absolute, and cannot be dependent upon full understanding of the event causing the application of control, and also complete grasp of the appropriate corrective action by the customers -- or local operators/maintenance. Absolute control also reduces the need for skilled operators, and in many cases, deletes the need entirely. The previous manual operator control and manipulation now can be by remote control from the network controller -- or his sub-area control. Only the network controller need fully grasp why an action is required.

In the past an orderwire has routinely been a separate channel. It may have been voice or it may have been teletype. Those who only visualize an orderwire as a broken box locator, believe that a teletype orderwire is nearly as useful as a voice wire, and on very simple issues related to electomechanical devices it proved to be adequate. In the future when rather more sophisticated and smaller degradations are to be detected, isolated, and corrected prior to failure, a tetetype orderwire will most often be inadequate. Complex problems need a voice to voice contact to assure understanding transfer. Thus, an orderwire is needed among key nodes, and key area subnodes.

However, the hardware assessment and reporting can be attacked in two ways. The network reporting and control can be by a separate circuit overhead orderwire structure (Fig. 5-14) or the control can be exercised within the normal communication channel (Fig. 5-15). There are, of course, advantages to both schemes. The network control constrained within the regular channel will appeal immediately to those individuals who believe that orderwires are an expensive and "nice" feature because no added channel requirements are imposed. One prime reason, however, for selecting this shared channel

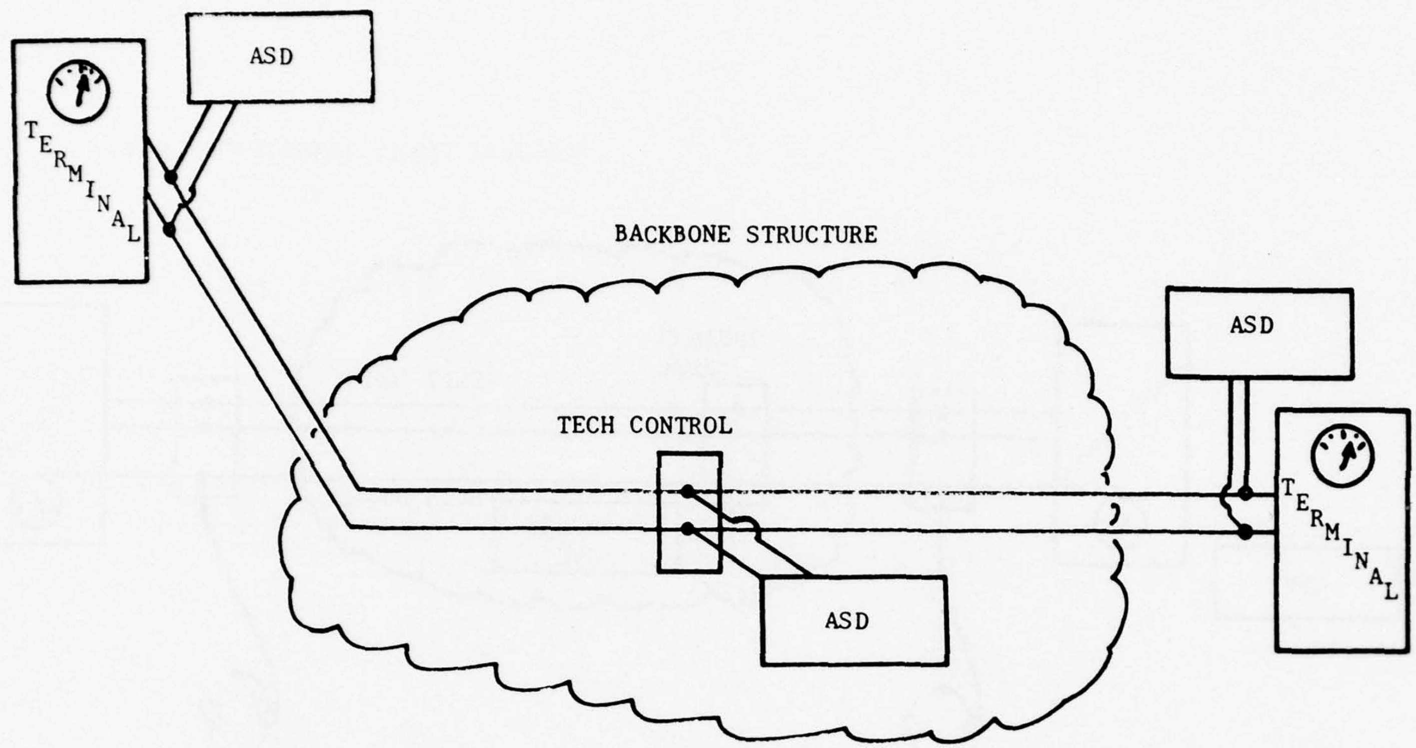
NETWORK SELF-ASSESSMENT SIGNALS ON ORDER WIRE STRUCTURE



ASD - ASSESSMENT SIGNAL DETECTOR

Fig. 5-14

NETWORK SELF-ASSESSMENT SIGNALS ON NORMAL COMM LINE



ASD - ASSESSMENT SIGNAL DETECTOR

Fig. 5-15

approach is much more sophisticated. There are many network terminals in out-of-the-way places, such as on small ships and in supersonic fighters, where a single communication channel is quite a feat and a second would be completely out of the question. There are other reasons, more esoteric, for electing the common shared approach. It will not take the average Sgt. very long to determine that the way to rid himself of undesired control actions is to disconnect or disable the orderwire, but leave the communication line undisturbed. Control signals and message traffic intermingled precludes this separation.

The other prime practical reason for selecting the "in channel" approach is because in times of communication stress, reroutes and alternate paths are inevitable, and the likelihood is much reduced of being able to reconstruct both a communication path and also a control orderwire -- and very likely, the control would falter or fail at the very times it is needed most. In the in-channel approach, both are handled by one reroute action.

There are some other reasons also, for selecting this common approach. All tech controls along the network routing will be able to observe both the communication flow and the control signals -- remember the control signals include the self performance assessment, information, the terminal distress signals, and other data of use to the backbone structure controllers.

The author prefers the in-channel approach, although it is likely that for some years to come, a composite of both approaches will be required.

The use of a separate orderwire has considerable merit from several aspects, and may be a valuable adjunct, even if the "in-channel" mode is standardized. A separate orderwire is easier to net, in that additional people can be added without undue complexity. The separate orderwire can be designed more easily with older or "low bid" devices. A separate orderwire may survive when the basic channel fails, and the command and control of the net may be easier to mechanically implement.

There is a capability, not yet considered by the DCS that is highly desirable from a system consideration. There are few terminal installations that do not have at least three major components. The communications device itself, a crypto security box and a modem, all are required to provide an operational network input/output terminal assembly. It is possible to assess the performance of the integrated three-part assembly or each device separately and report but one integrated answer. Until the design of the DCS can achieve a reasonably coherent and integrated form, the sophisticated performance assessment of assemblies is not likely. Nevertheless, the approach that permits the coupling of devices in the normal manner, and also permits the coupling of both the performance assessment and control mechanisms, is highly desirable.

As the DCS becomes digitized, the feasibility of in-band reporting and control becomes easier. The dedicated 2-way networks do not have many

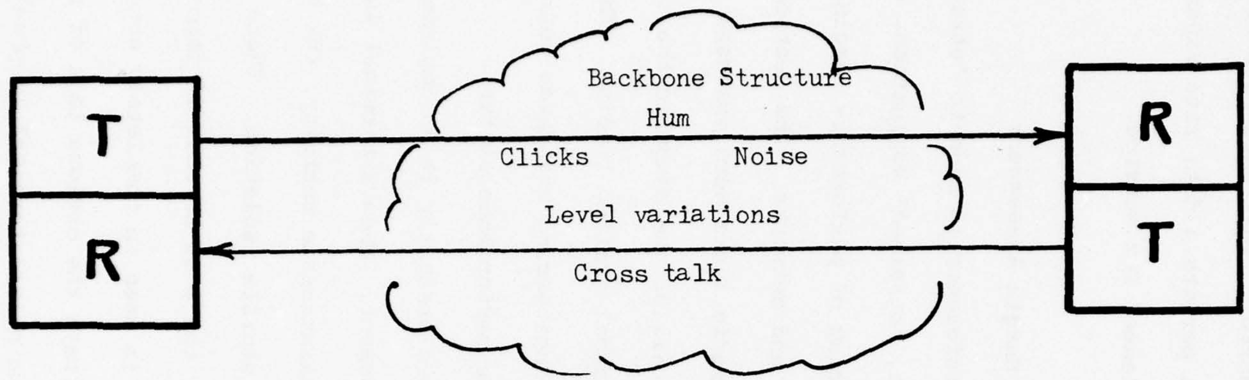
decode and recode operations, therefore, voice and data could easily be accommodated by use of a 16 KB voice coder, plus the basic data flow, plus a few hundred bits for reporting and control. This data rate fits well within a single voice channel and still permits a data rate capability of 48 KB overseas in the DCS or 40 KB in leased PCM service.

e. Terminal/Assembly Performance Margin Assessment

Throughout the SYPAC study, reference is made to 'stressed' testing, 'stressed' loopback assessment, 'stressed' evaluation, etc. This concept is basic to any real understanding of performance margins, and relates to both the backbone structure and networks. The section on the backbone structure described how the radio links were assessed audio to audio and the performance margin of all of the boxes in the total link was derived based upon the stress of normal traffic loading. The measured idle channel noise when compared with engineering standards derived when the link was optimized provides precise performance status.

In the network case, however, there presently is no implemented method to perform the equivalent assessment. When a terminal is suspected of being degraded or during periodic maintenance activity, the terminal is removed from service, and examined in sterile isolation. There is no traffic processing through the device, there is no channel imposing normal noise, clicks, or hum, and the device is seen in completely abnormal condition. Fig. 5-16 pictorially portrays the obvious lack of similarity between the actual terminal use and the normal terminal loopback test.

TERMINAL NORMAL USE



TERMINAL STANDARD LOOP-BACK (INCONCLUSIVE)

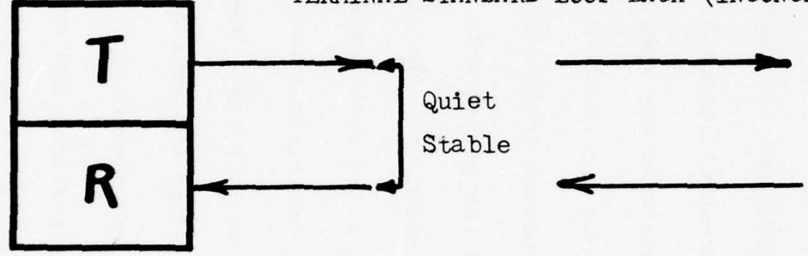


Fig. 5 - 16

It is not surprising that conclusions, drawn from the non-real life loopback test, are routinely in error.

Reference Fig. 5-17. The terminal's only view of the outside world is through the input and output circuit ports. It is clear by inspection that the stress artificially induced in this 'stressed' loopback path is similar to real life and can be made as realistic as is desirable and cost permissive. The signals now looped have those stresses, signal distortions, and extraneous, omnipresent noise and tones -- that are present in real life.

The approach to stressed testing was developed by the Operations Research Office for use by the Scope Creek teams for the various network performance assessments. A complete stress test must include: impulse noise, phase jitter, level variations, noise variation, phase hits, noise, power line hum, cross talk, autovon dial tones, and each factor imposed at varying rates of imposition. For example, there is in widespread DCS usage a data modem with excellent signal to noise advertised performance; and in fact, the signal to noise test as run with gaussian noise and using laboratory techniques validates the excellent contractor performance figures. In laboratory tests the gaussian noise is normally increased incrementally and very slowly with the signal held precisely at the optimum level, and the terminal performance recorded. This particular modem will work with about a 15 db signal to noise ratio. However, when the signal level is allowed to deviate a few dB from the optimum, the modem performance falls dramatically. The real world has level problems, so the laboratory data is not very typical. Of even more significance even at 40 dB (very

EFFECTIVE TERMINAL TEST

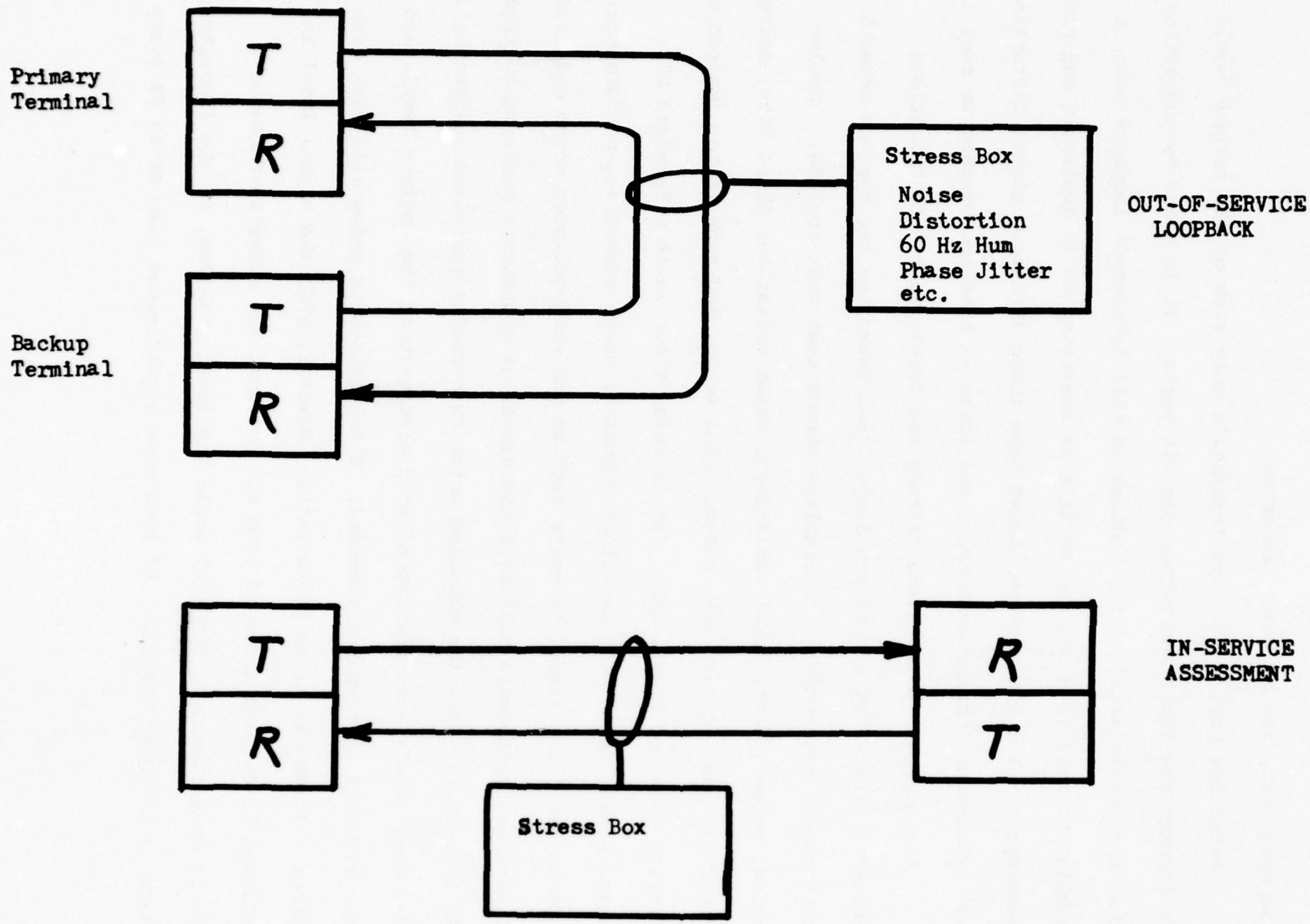


Fig. 5 - 17

good) signal to noise ratio, a 8.5 dB (one Neper) sudden shift in either the signal level or noise level, or both, causes severe bit error burst while the slow acting auto level circuitry readjusts, even though the signal to noise ratio still remains good. This one neper shift is not unusual in Europe. The modem has a design defect.

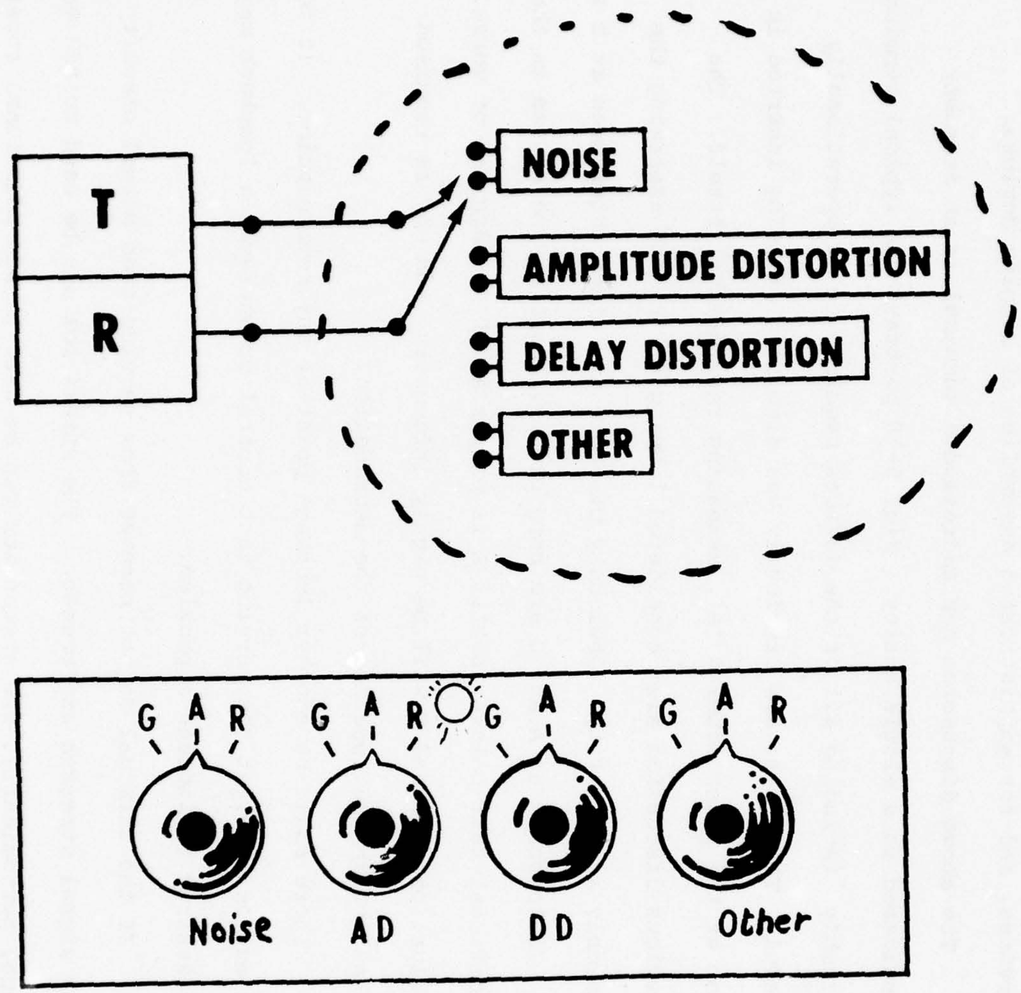
The goal of the stress testing then, should be to impose the stresses that are most disruptive of premium terminal operation. These particular stresses and the quantized degree of stressing must be determined during R&D characterization. Failing this, it must be assessed by the operational services. The 'like new' premium performance standard and also the amount of each type stress, as well as the interactions of the stresses that induce terminal maloperation or failure, must be derived. Practical facts of life force the characterization to concentrate on the two or three key disruptors of premium terminal performance. These are the parameters that will have to be simulated in the field for realistic performance margin assessments. The principle of this stressed test is to add the key quantized stresses to the signal to ascertain if the signal to stress ratio at which the device fails is the same as the 'like new' standard. This stress can be added either in loopback to device failure, or it can be added while the terminals are in-service, and the device stressed to a pre-set condition as indicated by internal sensors, as explaining in the terminal self-assessment section.

Envisage a device that when new could accept noise of -33 dBmØ with a proper signal level before a 10^{-2} degraded bit error rate performance

level results. At a later field test, the 10^{-2} degraded performance now results when only -40 dBm∅ noise is present. Clearly 7 dB has been lost and corrective action is needed. The 7 dB must be found even though the customer has not yet complained and in fact no degradation in day by day service may be visible to the customer. If the most sensitive parameter happens to be signal level, phase jitter or line conditioning, that stress is successively applied until the device fails or reaches a pre-set degradation reading on the interval performance assessment mechanism (This may be an in-service test), and the performance margin, the amount of the total stress that can be applied, compared to 'like new'. If the margin degrades, clearly a problem exists and the amount of reduced margin quantifies the difficulty.

Fig. 5-18 portrays a simple generic stress device. In this example, the device is a data terminal of typical design. The stress box can add noise, amplitude and delay distortion, and degradations such as signal level changes. The calculated thresholds are preset. Thus to evaluate this terminal, merely loop-back and individually select a stress and flip the knob to Amber and Red. The terminal should be just at the edge of failure on Red, but still operational. On Amber, the terminal should be fully operational, but the built-in self-assessment should show some degradation. If the Amber stress induces high degradation and the Red stress produces a full failure, the device is in poor condition and requires attention. Several stresses can be induced simultaneously when required.

TERMINAL EFFECTIVE SELF TEST



STRESS BOX

Fig. 5 - 18

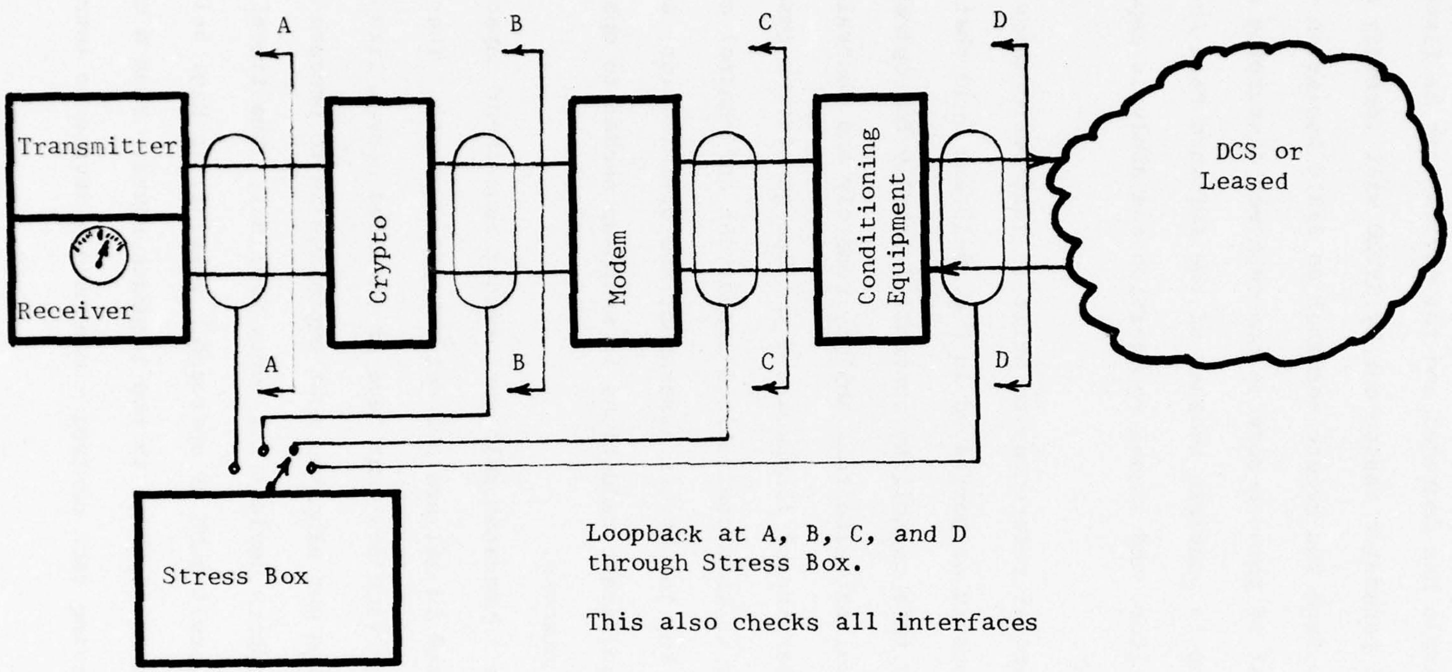
In SYPAC the preset threshold approximation or the actual db quantized stress approach can be used. The former is suitable for unsophisticated administrative and clerical users, the latter best matched to critical services, and for sophisticated assemblies of complex devices.

The above discussion has addressed a terminal or an assembly considered as a single entity. Fig. 5-19 portrays the typical terminal assembly including all of the devices required to be operationally useful. The stress box previously was discussed as being inserted in the loop at the point labeled 'A', assessing the terminal itself. The previous discussion also considered looping at 'D' and assessing the assembly as an entity. Obviously there are two other interfaces at B & C. If loopback at A and D are both proper, there may be no use in the additional test points, but if A is proper and D is marginal or worse, evaluation at B and C will be highly informative and may be required to ascertain the location of the degradation.

There could be another loopback point at any remote point. It could be on the base, at the serving tech control or wherever a loopback may be desired to isolate a problem.

If the terminal is not removed from service then normal circuit and signal stresses are present. The stress box can be used to add more. Thus, periodically, the stress box can be used to add additional stress while monitoring device performance. SYPAC can be used to measure the sum of the normal plus added stress. If the amount of total stress that can be accepted before reaching a pre-sit level of performance reduces, the

TYPICAL TERMINAL



Loopback at A, B, C, and D through Stress Box.

This also checks all interfaces

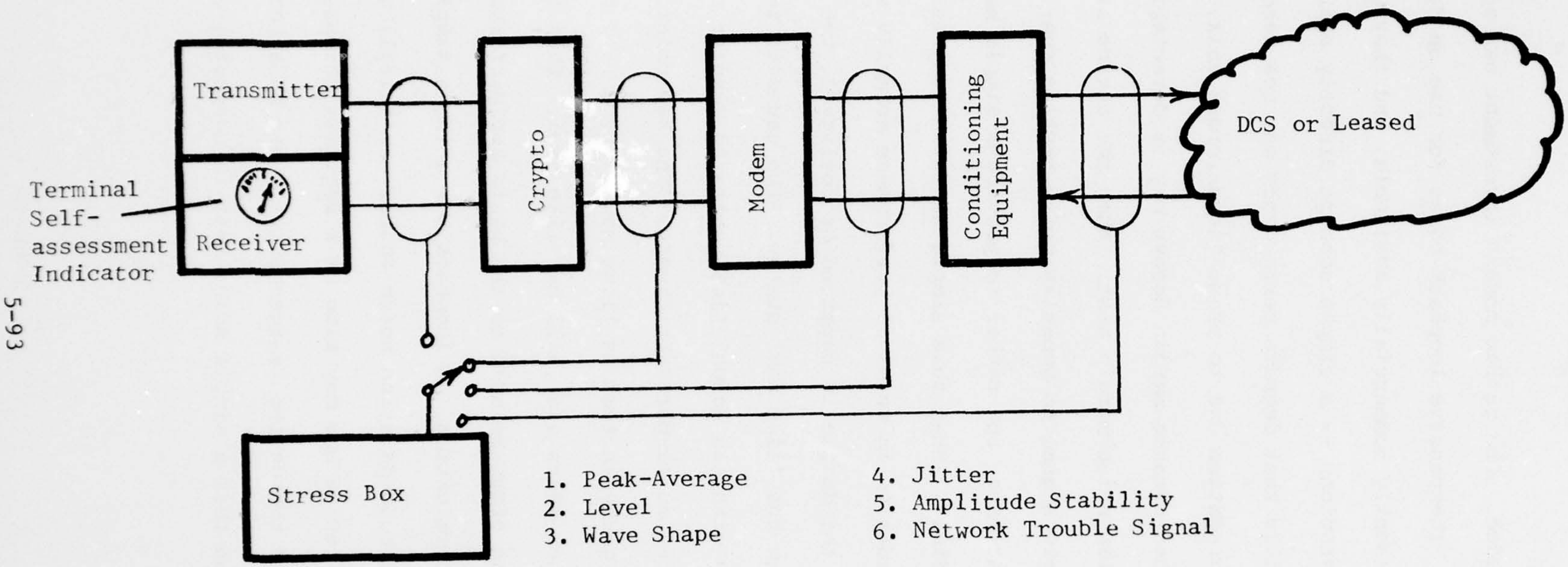
Fig. 5 - 19

performance margin has degraded and the device must be fixed. The in-service signal parameter assessment by SYPAC will identify any circuit/signal deteriorations from the remote terminal so fault isolation will not be difficult. All of this in-service non-customer disturbing assessment and fault isolation is possible because of the software fast Fourier transform and digital filter, and signal recognition and analysis capability, proved by ATEC.

In the earlier references to built in self-performance assessment, it is both concepts as portrayed in Fig. 5-19 and 5-20 that is envisaged. It is not only this capability controlled locally for operator and maintenance use, but also this ability remotely and centrally controlled to assess in-service or loopback and produce quantative results that is required. It is this centralized assessment and control capability that really is the key to network assessment and optimization, and concurrently to provide significant reductions in manpower needed to operate and maintain the networks.

The above integrated self-performance assessment capability clearly must be required in all new DOD network procurements. There are many terminals in service now that have an extended normal life expectancy. The obvious solution and also the most expensive is to procure stressed assessment/loopback devices for every terminal. The fiscal plight of DOD will not permit such an approach. However, in Fig. 5-19 the stress can be introduced anywhere in the loopback route. Thus a centralized spot - the serving tech control - can have a device to introduce all of

IN SERVICE CHECKS
(SIGNAL CHARACTERISTICS)



1. Peak-Average
2. Level
3. Wave Shape
4. Jitter
5. Amplitude Stability
6. Network Trouble Signal

Fig. 5 - 20

the stresses needed. One rather modest investment can adequately serve most terminals. Inexpensive loopback boxes for use on devices not so equipped are presently commercially available, and they use in-band tone controls for operations -- a simple concept directly usable in the DCS.

All parameters that degrade performance may not need to be checked. Often as the degradation due to phase jitter,cross talk, or line conditioning increases, the performance margin decays may be detectable in a degrading signal to gaussian noise margin test. When the device is at premium peak alignment a simple signal to gaussian noise test is run; to give, not a performance estimate, but rather to provide a simple measurement standard for use in the field. When this simple gaussian test is applied in the field, any degradation in terminal performance normally will be evident. Conversely when the device is repaired or realigned, the gaussian test should recover to the 'like new' status. The gaussian test results do not degrade linearly with the actual field stressed results nor with the properly conducted multi-parameter tests. The key point, however, is that when the simple gaussian test is 'like new', there is a high probability that all the other tests also will be 'like new'. Thus this simple gaussian test can often be used as the basis for performance margin 'equivalent' determination. A loopback box using a simple signal level attenuator and pseudo-gaussian noise source can fulfill most terminal loopback needs. 60 Hz hum may also be a required stress, since it is ubiquitous and if the device is susceptive, must be a test ingredient. The determination that a simple noise test is adequate, or whether a

special stressed loopback test box is required must be made prior to or during the operational testing to permit the tester provisioning with the entry of the device into operational use. A stress box was acquired for a modem used in a very important ground-air dedicated network. Of the first modems tested, in the first Scope Creek type evaluation, none came within 5 dB (a factor of 3) of 'like new'; the worst one was degraded by 17 dB (factor of 50); and most were off by about 7 dB. Yet all were classed as 'green' because they would work in simple D.C. loopback. Meanwhile management complained about everyone throughout the rest of the network. The failure of a box or a channel in a network always results in a frantic effort to restore the route using a pre-set restoral plan. This always assures an outage, however short. Using the in-service stress concept and the self-performance assessment indications, the net control can initiate the repair of a degraded terminal, or direct an alternate route for a good terminal as appropriate before failure of the service.

The degree of sophisticated analysis permitted by these capabilities is limited only by the imagination of the backbone structure and the network controllers. For example, after a degraded terminal or link repair is completed, the final clearing agency will be the Net Control who will send a special stressed test message and observe the self assessment results.

In addition, for best control of critical networks, the internal capability to loopback toward the tech control, upon a remote instruction, is very useful for several purposes. It permits automatic testing and assessment of terminals from a central point upon demand, during off

hours on a routine basis, or as required from a customer viewpoint. It also permits centralized and automatic total network checking with no need for personnel at the terminal locations.

It will be recalled that economics will probably not permit the self-assessment and the remotely controlled loop back capability for each small interfacing devices throughout the network. But when a terminal is looped, the loopback test checks not only the terminal but all serial devices from the network node to the terminal, and on the return path. A simple test message can be generated and the message can be looped at the outlying terminal for retransmission back to the network node. Errors picked up or other degradations can be easily checked automatically. This remote control loopback mechanism also is an effective way to control a communication network. The remote user knows when he is locked out, but the locking message flow proves that his channel is still working.

The goal of the stressed performance assessment is not the academic one to achieve 'perfect' alignment. Rather it is required to assure that the terminals retain their performance margin and thus can be reasonably expected to funcion when hostilities, lack of logistic support, weather, or other mishap degrade some portion of the total system serial with the concerned terminals and to be sure that managers understand the true status of the network hardware.

4. Switched Networks

a. Networks Discussion

There are two general subdivisions of switched networks; normal and normal with preemption.

(1) Normal Switched Network

A switched network is the most common type of network. An example is the Bell Telephone System that places phones in most homes. The purpose of a switched net is to temporarily interconnect on an 'as required' basis one individual to another of the network subscribers. At the termination of the call, the interconnection is disestablished and the facilities are available for use by other customers.

These switched networks can accommodate large numbers of subscribers and require a minimum of fixed plant for the services provided. These networks require no community of interest, no geographical constraints, and are flexible -- data services as well as voice may be provided.

These type networks normally function well for non-critical missions. The quality of service is reasonable -- Bell expects to give the user acceptable service 95% of the time. Bell frequently does better; but on Mother's Day, Christmas, during storms or similar events with other than a normal call distribution, they do much worse. By suitable statistics the service probably could be shown to be 95% if averaged over the year. Since most calls during these overload days can be replaced many times until completed, with no real impact, such statistical rating is reasonable; and people don't even recognize that their telephone gives only a finite

'likelihood' of completing the call.

It is interesting to note that several years ago, a young hippie who professed no need for money, inherited several million dollars. He was interviewed by the press and substantiated his position by stating that he would give money to all who needed it. The press made available the man's phone number. The resulting number of phone calls not only swamped the young man, it synergistically and systematically clogged the Bell telephone network. The jam was not just in the local area alone, but spread across the eastern half of the country. Bell was forced to laborously identify and isolate the magic phone number, then block this code at their switches to restore the system. Hardware control was the only way to control,and load allocation clearly failed for an extended period, and service was denied many customers -- far more than those trying to contact the new millionaire. This one event could not be classed as even a minor national emergency, but it effectively crippled all East Coast communications.

Figure 5-21 is a portion of a switched network drawing as normally published by both the commercial carriers and by DCA. It shows the switches and the interswitch trunks, but does not portray, even conceptually, the existence of subscribers. The subscriber is assumed to be a point on a statistical call distribution curve. The structure portrayed is assessed to some degree by Bell and other network operators because it is clear that failure of switch G or the trunk between C and G will impact service for all customers terminated on switch G. Failure of a single subscriber call, however, is not viewed as a significant event and in fact is not considered

SWITCHED NETWORK AS NORMALLY PORTRAYED

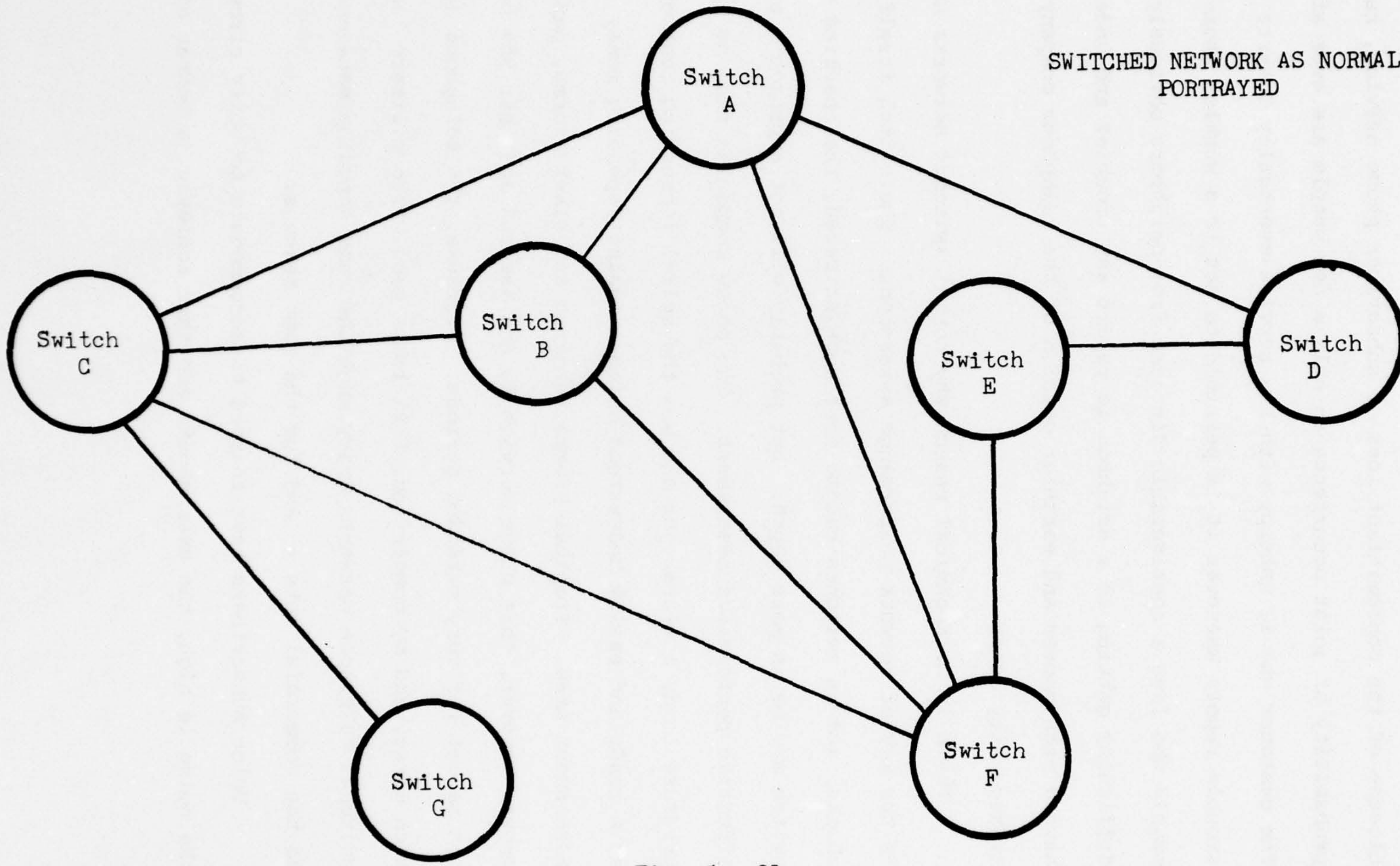


Fig. 5 - 21

at . The loss of home from fire, or death of a person after an accident, because of the concomittant loss of subscriber phone service, has a low probability of joint occurrence so only a few people are ever affected. The customer who is unhappy with his service eventually inserts his own trouble report whenever it is possible to get to a working phone. Farm people who live a considerable distance from neighbors obviously have more difficulty getting to a neighbor to report any troubles and understandably have a much poorer and earthier opinion of the telephone company than the average city users.

There is no technical reason why normal switched networks have so little in the way of network performance assessment. The switch itself has some checks, and as switches become more sophisticated, the checking of the switch may be in more depth; but probably will not approach a truly effective performance assessment. The phone companies feel no real pressure to do a better job and use the spiral increasing cost of service as a ready and easily understood defense against spending money in the assessment area. Tropical storms,tornados and sleet storms, periodically prove, however, that phone service is not assured and that 95% service may not be met for very extended periods. Overseas, the telephone service is even worse, and by comparison, Bell looks good. The military 'on base' switched telephone networks enjoy much the same sanguine management concepts as the commercial nets -- and for the same reasons.

Voice subscribers have learned to accommodate to noisy circuits. When the noise is high, the user shouts and thus achieves a better signal to

noise ratio. Speech is highly redundant in information content and the human ear is very effective in extracting intelligence from noise. Thus, people manage to use whatever is provided and complain only when a call cannot be established at all.

For data networks the same channel noise and quality problems abound, but data terminals are far less flexible and are unable to accommodate to less than proper conditions. This is why many people believe that data networks are harder to manage. They are not. Data terminals are just unforgiving and completely unambiguous. When the network level of technical performance fails to suit the data terminal, it complains clearly, absolutely and every time by failing to operate. The terminal does not respond to managers'excuses that the problem is at the other end of the circuit, consequently managers are forced to face the real network problems.

All of the technical comments appearing earlier in the sections on Broadcast and Dedicated nets hold for switched networks. However, the addition of switches adds an order of complexity and also introduces probabilistic parameters, but at the same time switches give the opportunity to increase the performance assessment and fault isolation capability.

Yet there is another factor that subtly impedes more vigorous military performance assessment and management. The pressure from the budget always tends to push the DOD to use commercial 'off the shelf' items 'because it is cheaper.' If an 'honest' cost of life cycle ownership accounting were conducted, the use of low bid off-the-shelf equipment frequently would not save money and would be manpower expensive.

The approach really produces higher total cost and lower performance. However, the cost of ownership of a full military version is biased to some degree by the development costs, even though it might be more than recovered by lower operating costs. The likely most cost effective approach for the military is to procure, as the basic equipment, commercially available quality hardware and pay for effective performance assessment applique features to permit acceptable integration into a military communication system and provide premium service with minimum personnel requirements.

Clearly, the optimization of switched networks needs to be examined to assure acceptable service at minimum total life cycle cost. This is certainly a larger problem than just minimizing the initial hardware costs.

(2) Switched Networks with Pre-emption

There are few commercial examples of switched networks with the capability for selected customers to pre-empt the facilities. Within the civilian community, there is little apparent need and so there is no commercial production of such equipment. The military has one major network of this type, Autovon, but it is the heart and soul of the entire military administrative and a part of the command and control communication structure. As such, it warrants a position of note and considerable study.

The switched network with pre-emption is basically just another switch net, unless one or more subscribers exercises his assigned option to insert his call processing ahead of other customers. There are procedures that govern the electronic equipment response to the various types of pre-emptions.

In theory -- but not in practice -- each subscriber is supposed to decide whether his call fits the criteria of a precedence call. If his communication relates to "successful conduct of the war", "immediate operational effect on tactical operations", or "immediate bearing on national security", he should exercise his option to go to a higher priority and seize equipment that may be in use at a lower precedence.

The principles are clear and the concept is workable; however, there is little control on use of priority pre-empts. Assigning phones capable of Flash override to persons of rank does not either provide control or appropriate usage. It is optimistically presumed that the higher ranking officers and civilians understand the pre-emption criteria and use due restraint, however, tests in the field overseas show otherwise. An "Immediate" precedence call (situations that gravely affect the security of the nation) has little chance for survival, unpre-empted for even 3 minutes on the longer circuits, and many times cannot even be established. Clearly, the prior system is much abused, although the degree of mis-use is not yet even documented.

Further, since the basic switched network is the same as the regular telephone network described above, the performance criteria is still keyed to "a probability of service" concept. Add-on boxes have been appliques to a few selected switch access phone lines to periodically test selected circuit features and to give an improved probability of accessing the switch, but the network is in reality neither assessed nor controlled.

In cases of high ranking users, more than one access line to more than one switch may be provided. This is a case where money is used to

replicate the structure and by so doing increase the probability of successful service. This is an expensive way to compensate for lack of assessment and control.

Network traffic control is routinely done in the civilian world on a slow time basis. The goal is not to stay in phase with rapidly shifting traffic demands, rather it is to slowly mold the networks to such factors as changing housing patterns, expected new business centers, or other matters with time relevance of months, or years. As such, traffic count in a particular switch is a periodic matter, not a real time issue. Inter-switch trunk usage has a more direct money relationship so it is given more frequent attention.

In the military, real time control of the whole network is a basic need, since a call uncompleted during a critical event may be too late at any subsequent time. The military cannot procure a sophisticated network with appropriate controls off the shelf, because industry has no similar need, and so no commercial equivalent, off the shelf hardware is available. This point cannot be over-emphasized. The military must solve this 100% service problem themselves. The TTC-39 switch procurement is a partial recognition of this fact.

A switched network is a technically more complex form than either the broadcast or dedicated networks. The specific interconnections are not known to the designer or to the subscribers beforehand. The subscribers observe no protocol except that imposed by the network hardware or by hardware controls. Customers normally do not recognize any procedures to ease their own use of the network. Almost by definition the number of

subscribers is large and at any given time no one knows who is using the net.

These truths seem so imposing that many managers subscribe to the 'if it works leave it alone' management philosophy. This would not be altogether a poor approach if there were an effective method to assess 'if it is working'. Unfortunately, the customer complaint as an assessment and reporting approach is a failure only alarm concept. Thus, little if any management of this class network occurs until service has been denied.

Most discussions and technical papers concerning switched networks start with the switch. The pictorial representation is often a circle for each switch, with lines drawn among the circles in a manner that optimizes some parameter of interest. The discussion discards reality by assuming that the customers arrive at the switches on magic noiseless and troublefree lines and traverses all peripheral devices at the switch site with no possibility of trouble. Further, the discussion routinely rejects real life by defining all customer network usage, as independent and random events according to a Poisson distribution. Perhaps this is a reasonable assumption for most commercial and military services in peacetime, but it is obvious that this load distribution would not hold during the early hours or days of a national emergency or a war. Assuming that all hardware elements function correctly, the pre-emption, as installed on AUTOVON, and priority handling of messages as built into AUTODIN will permit somewhat functional operation to emerge even though the Poisson distribution suddenly is not random or independent, but is triggered abruptly by a severe event affecting all net users. The military managers cannot afford

to relax and depend solely on priority and pre-emption as the only service assurance latitude available. Hardware unavailability due to defective equipment, degraded performance margins, poor operation and maintenance, or hardware damage precludes such happy service promise. Further, there are numerous examples of poor service on both Autovon and Autodin even in the present relatively unstressful detente situation. The movement of a few hundreds of HQ personnel, such as the recent move to Ramstein AFB, Germany, causes -- or more accurately highlights -- the incipient communications problems abounding all through the structure. The present DCS reports show that Autovon switches for example are 99.9+% available, and from this,people illogically presume that the network is working well. Further the 99.9+% means only that the switch is "not down" -- this is not the same thing as the switch is properly processing all requested calls. Clearly there is more to customer service than the switch efficiency but as of this date no performance assessment concept is implemented to honestly, technically, and operationally evaluate the switched networks -- as the subscriber sees the service. The commander with his four wire direct switch access phone instrument may get better service than those personnel with more mundane jobs and dial '8' service. However, there is reason to believe that there is often a better grade of service available to the normal Autovon user who accesses the system through a manual exchange. There is nothing magic about the manual PBX or its access lines to the switch, but there is a flexibility, adaptability, and general competence that is provided by the PBX human operator than cannot be matched by any electronic contrivance. These operators find ways to work around problems, they

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SYSTEM PERFORMANCE ASSESSMENT AND CONTROL CONCEPT (SYPAC)
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avoid marginal or poor portions of the structure, and they continually reprogram themselves to put a call through even though its path is obviously less than the most direct and 'logical route' and they use what priority they need to complete the connections. Unfortunately operators are too slow and are expensive, but nevertheless, they are effective in completing calls.

The biggest impediment, by far, to really major improvement in network performance is the superficial view of the network held by most engineering personnel, as reflected in Figure 5-21. Theoretical papers from universities concentrate on the mathematically challenging aspects of routing, queuing theory, and sophisticated concepts for intercourse among the switches themselves 'to optimize facility usage.' The lack of subscribers is easily handled by assuming call inputs described by some distribution, tractible in modern computers. The crisis call distribution is not yet described by math formulas and so would make the problem 'hard'. Further, 'call completion', not 'efficiency in facility usage' is the military optimization goal, and optimization for one is far from optimization on the other.

Industry concentrates on those aspects of switch state of the art that will enhance their likelihood of selling new switches or developing a commercial product saleable in quantity. The government draws most of its engineering talent from schools or industry and so is inclined to concentrate on switch matters also. Military communicators in general have not developed the technical expertise to view an entire switch network as an entity.

Although switched networks are the life blood of the DOD, these networks have remained esoteric.

The genesis of this unhappy condition is easy to understand. The solution, however, is that the DOD will have to develop its own experts, or recruit very selectively from Bell, the only other really systems organization, and retrain them on military requirements. The lack of systems grasp, however, should not be too difficult to correct once the learning charge has been correctly stated, and the goal and objective of full performance assessment and network optimization user to user clearly established for the DCS. The system goal cannot be met solely by assignment of additional people. These network people must be carefully selected from individuals who understand theory, but who also have a practical grasp of details of field problems and hardware operation. Generally it is not the theoretical aspects of the design of the hardware that precludes acceptable system service, rather it is poor system design and integration and routinely poor operation of some hardware compounded by software difficulties. The switch control electronics are rarely the source of the problem, as the switch reliability figures portray.

A prime difficulty with all switched networks, Autovon, for example, is the poor operation of some or all of the long sequence of miscellaneous boxes, cables, converters, sensors, amplifiers, attenuators, conditioners, interface connectors, etc., etc. that are serial on all calls. The telephone instrument itself is always serial and it is involved not only while the conversation is underway, but is a necessary serial element for

the signaling that establishes the call in the first place. Some managers will recall the false ring and dial pulse length problems.

Management personnel and many military commanders have felt that telephone networks do not work as well as desired, and some selected technicians have known that the digital networks were not operating correctly, but lack of effective network performance assessment precluded any really meaningful quantizing, so the communication management structure was ineffectual in directly addressing these fears. Special teams were formed on occasions to solve specific chronic issues that did surface, but no real total network fix action occurred and performance remained much sub-par.

Tests conducted recently, at several Autovon switches, showed that some of <u>all</u> interface elements were degraded and additionally some of <u>all</u> interface elements were completely defunct. The percentage of each element sufficiently degraded or defective to cause trouble in network operation was high. Based upon a medium size sample, by the author, troublesome elements of each type would be more than 15% of the total population.

The figure of 15% is not restricted to interface devices at the switch sites. Tests made to local PBX's indicated that this is a reasonable number also for base related hardware. Thus, obviously a performance assessment approach to identify these degraded and out of service elements is critically needed. Taking only slight liberties with probability, a call through 4 switches and associated peripheral boxes would have just a 50/50 chance of satisfactory completion for switch and network hardware reasons alone.

There are other interface boxes that are troublesome. Jack fields are known to be noisy as is the wiring among bays. Clearly performance assessment must address these interfaces. It is obvious that the existing introverted software switch oriented 'self-assessment' concepts are absolutely not acceptable for network assessment.

In another network, an evaluation of several Autodin switches by a military service found generally 'excellent' switch maintenance. After reading the reports in detail, however, this bold and all encompassing statement was wrong. It should have stated, 'The electronic card circuitry portion of the switch controls appear to be well maintained.' This is a far different conclusion, and much more illuminating. The report documented patch bay problems, memory drum difficulties, line termination troubles, input and output terminal malfunctions, unauthorized wiring changes in devices, the Monitor Console out of calibration and instruments missing, hardly 'excellent'. The report's misleading statement was made probably because most of the identified problems are not the assigned responsibility of the maintenance men who repair the electronic cards of the control portion of the switch. These 'switch' maintenance personnel are not responsible for, nor in fact are they concerned or interested with, the defective elements elsewhere in the switch. This fine line of demarcation that permits a team to give accolades to a sub element of part of a switch while the service provided by that switch is poor, is of no relevance to subscribers. Operational commanders are not interested in subset performance since they only use the total network when they try to communicate. Thus

communications managers must expand their thinking to share the network point of view.

Further, a recent industry survey of industrial large scale computer user satisfaction found a simlar situation. In general, computer mainframe reliability for all suppliers was high. However, one or more of the supportive peripherals failed to provide suitable performance in almost every installation. The large scale computer installation is roughly equivalent to a switch node. Thus the fact that a switch works well, but the network won't function acceptably is not purely a military problem, and derives from the same lack of system grasp.

The control of a network has as yet not really been attempted. The concepts, possible approaches, and likely payoffs are as yet not well understood in the field. Conceptual acceptance of the need for improvement is the single biggest obstacle to be removed before this class network can be successfully assessed and controlled.

(3) Performance Assessment Concept

The SYPAC concept of network control starts with network performance assessment. Such assessment must be focused at the switch.

It is easy to understand that if the switch is inoperative, intermittent, or defective, some or all of the information flowing through the switch must be degraded or destroyed. Thus, there must be a series of assessments that test the operational and technical condition of the switch. If there are several switches in the network, each switch must be tested. The

simplistic switch test routines now run are 'good', but clearly are not 'sufficient.' In general, these routines were designed to isolate switch electronic component hard failures. There is little self test capability for assessing problems such as timing disparity among central processors, memory drums, or other matters such as wave shape distortions of signals in the interswitch wiring, connectors, mismatches at the switch interfaces with the outside world or cross talk in the critical bit threshold circuits.

Once the switch is assessed (and acceptable) the peripheral and interface devices that the switch uses to couple into the interconnecting backbone structure must be checked. The assessments must incrementally extend the scope of the assessments, from the immediate switch locale, ever farther, until it reaches the adjacent switch through all interface devices at both sites. These tests must assure that the switch to switch framework is acceptable and that all degradations, if any, are quantitatively measured and recorded for analysis. Any condition nearing Red must alarm immediately.

The next step is for each switch node to sequentially view the path to each terminal, test the terminal itself, then by terminal loopback, terminal self-assessment or terminal signal analysis, assure that all hardware and interfaces are proper. This will prove difficult in many networks that were assembled, rather than designed, and for which little terminal or interface criteria was ever known.

Figure 5-22 is a simple portrayal of a portion of a user Autodin interconnection. This figure shows the send and receive side of an Autodin customer. Obviously there will be a very similar mirror image to

AUTODIN MAJOR NODE / SWITCH ASSESSMENT

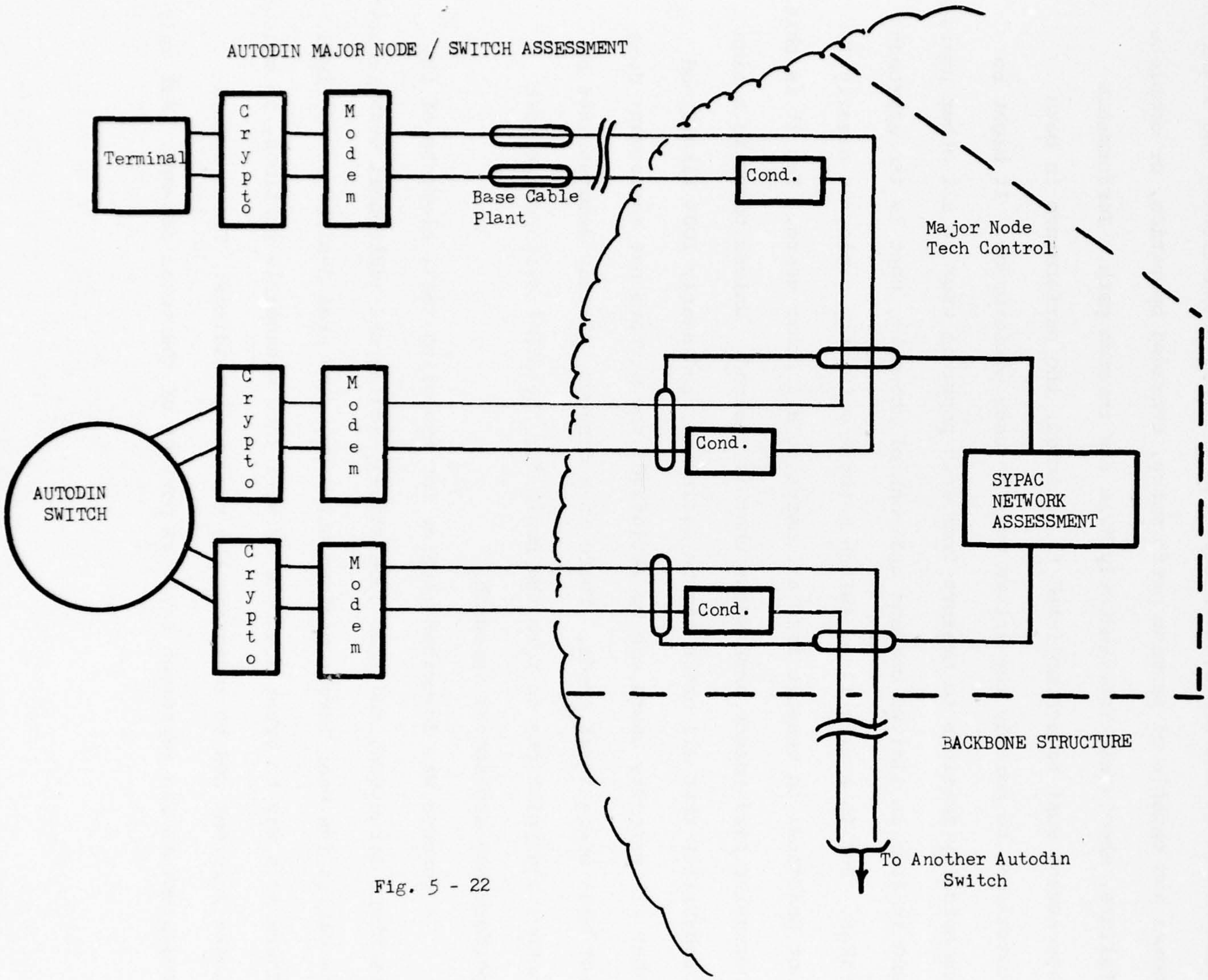


Fig. 5 - 22

represent the hardware sequence for the other customer. Thus, Figure 5-22, plus the mirror image would represent the user to user picture. The interconnection is all 4 wire, meaning each direction is completely independent of the other, with separate hardware, conditioning and signaling boxes and capable of premium performance, degraded operation, or complete failure, absolutely independently from the reverse path. Performance Assessment must be accomplished to ascertain the performance in both directions, to portray the entire user to user performance. It might be technically feasible to measure from each possible user to all other users, and in fact in limited command and control networks, that is the approach taken. But in a wide flung switch network with many users, it clearly is not practical to measure from all users to all other users. Yet it is this pervasive performance assessment that is desired. Unless there is a high probability that all users can be satisfied, and nearly 100% likelihood that all priority users can be satisfied, the performance assessment does not meet operational needs. There is a concept, already demonstrated by manual manipulations to form the basis for the SYPAC switched network performance assessment approach.

A concept was described earlier for assessing small elements of the backbone structure, and then cumulatively adding the additional measurements to derive the ever larger picture until any size area desired was defined. There is a way to break down the network into manageable portions, to measure these portions and to integrate the resulting readings. These summed measurements can represent any size portion of the total network. Not only

is this approach viable, it is also amenable to automation. Further, it is reasonable to decentralize the actual assessment to a number of net sub-divisions. These subdivisions are centered at the switch nodes.

Autodin is not normally envisaged as a switched network, but a store and forward configuration is really but a time sequenced switched net. Because of the somewhat simplier layout, the Autodin net will be used to first describe the SYPAC network performance assessment concept. Later the concept will be extended to cover Autovon and other real time switched nets.

b. Autodin Network

Presently, the Autodin network is a worldwide common user digital network, interconnecting all three services and DOD, and selected non-DOD agencies. The inputs and exits from the network are through a wide variety of digital terminals encompassing low speed teletype rate customers, and graduated up through high bit rate devices. This digital network was not originally designed as an integrated communications network but was a conversion from the original design as a logistics network. This network provides effective data communications, in general, for most of the customers, most of the time. This apparently happy grade of service, however, must be evaluated in light of the fact that many elements such as terminals were dualized to provide service in case of failure, when one operational box could actually handle the traffic. More important terminals have access to more than one switch to increase the likelihood of entry into the

network, and the switches have multiple routes among them so that the failure of one switch does not render the network inoperative. The processing portion of the switches are duplicated or triplicated. Even with these overkills, there are times when customers are denied service, and probabilities will decide whether these denials have little, some, or major effect on the users of the network. It clearly would be better and obviously cheaper if all equipment could be installed singularly and have degradation measured, failure predicted and corrected prior to operational impairment.

(1) Performance Assessment

The techniques were covered earlier for assessing the performance of a terminal. The uninformative and frequently misleading simple direct loopback was discussed and discarded in favor of the terminal loopback to a standby terminal or to itself through an external, or built-in stress box. These out of service loopback tests are both informative and are quantitive. Unfortunately, this requires at least a period of down time. If the function were automated, the time out of service would be quite small. While such shutdown is not disturbing to most subscribers, a few object -- for valid or other reasons. "In-service' terminal assessment by actual signal analysis when coupled with built-in self-assessment makes the ideal alternative to out-of-service testing for most occasions. Obviously, the less agreeable a subscriber is to down time, the more agreeable he must be to the small increase in cost for the in-service built-in self-assessment. Of more importance is the obvious conclusion, that the more an application

deviates from standard commercial practice -- that is if full time uninterrupted service, no routine periodic down time, and priority usage, etc. is required -- the less a standard commercial terminal can meet the operational need. The alternative is the present approach that more than doubles the hardware, maintenance, and installation costs by complete duplication of terminal and all peripheral boxes, so that assured performance has at least a chance. A less expensive alternative is to applique or retrofit a performance assessment capability on mass produced terminals. As was mentioned in the earlier portion of the report, these applique techniques have already been field demonstrated and proved practical.

It is obviously desirable to apply the in-service network signal analysis approach for assessing the interface and circuit problems. If there are no problems, there is no need for further efforts. However, periodically some devices too small to warrant self-assessment, or some intermittent degradations in cabling, etc., need to be addressed. Thus there must be a way to approach these potentially network disruptive problems.

A switch can call up any route desired and can hold it indefinitely for manual or automatic examination. The switch will be able to establish the special configuration and SYPAC will make the measurements desired quickly so little operational impact need result. However, if the network suddenly requests the facilities under test, the switch can respond in any way programmed. The facilities can be held or can be conditionally held

until a high priority request for the resources. If a path or interface has failed, obviously the loopback would be held up. Thus, stressed loopbacks can be incorporated as a viable DCS technique for any automated network with predictable and software adjustable operational impact.

The switch can be the source and also the receiver of the signal. It can be considered only a rather involved terminal. There are normally several independent processors and spare input and output devices so the allocation of the spare processor or the time-sharing of the on-line processor is completely feasible. The switch can be looped at A, B, and at C. (Fig. 5-23a.) This is done now occasionally by manual interconnection, but as explained in detail in the earlier section, a simple loopback is a poor technique, and since it gives unquantified results, it is unsuitable for trending, and leads to internal conflicts among maintainers because of ambiguous results when taken several places in the troubled interconnection. The loopback signals must be stressed in exactly the same manner as in the terminal case if the results are to be valid. The use of a Stress Box permits each box, each set of devices -- crypto, modem, and conditioning -- to be checked with a precise numerical performance margin indicated. Degradations are easily detected and quantized in terms of decibels that are understood by all maintenance men.

As indicated in Figure 5-22, there is another class of communication access to the switch, besides the customer lines. The Autodin network switch accepts a message and shortly thereafter forwards the message to another switch nearer the delivery point when the intended recipient is not

connected to the accepting switch. This inter-switch trunk (IST) is the other class of switch access line. In principle it is the same as any other access line and can be assessed by using exactly the same stressed techniques.

There is a further capability available to the Autodin switch node based assessment (see Fig. 5-23a), and that is to be able to loopback at points D through H. There is no present hardware installed that can be remotely placed in the loopback mode, but remote switching is not a technically challenging issue, and could be procured commercially and installed anytime desired -- and should be.

Figure 5-23a portrays the terminal as terminal #1, or N. This is intended to show that once all of the interface hardware has been assessed at the switch, each sequential box all the way to and including all terminals #1 through N can be so assessed. This assumes that the terminal signal characteristics, operational performance, or self assessment are degraded or other reason exists for such additional fault isolation. The proper performance assessment margin will vary somewhat among terminals of a particular type because of the differing distance traveled in the backbone structure between the switch and the various terminals. There will be differing margins for terminals with differing bit rates. It is practical however to assign a single performance threshold for each terminal class without significant impact on the network assessment concept, or on long and difficult paths a standard tailored to the unusual situation can be applied with only a simple software change.

AUTODIN NETWORK ASSESSMENT FROM THE SWITCH

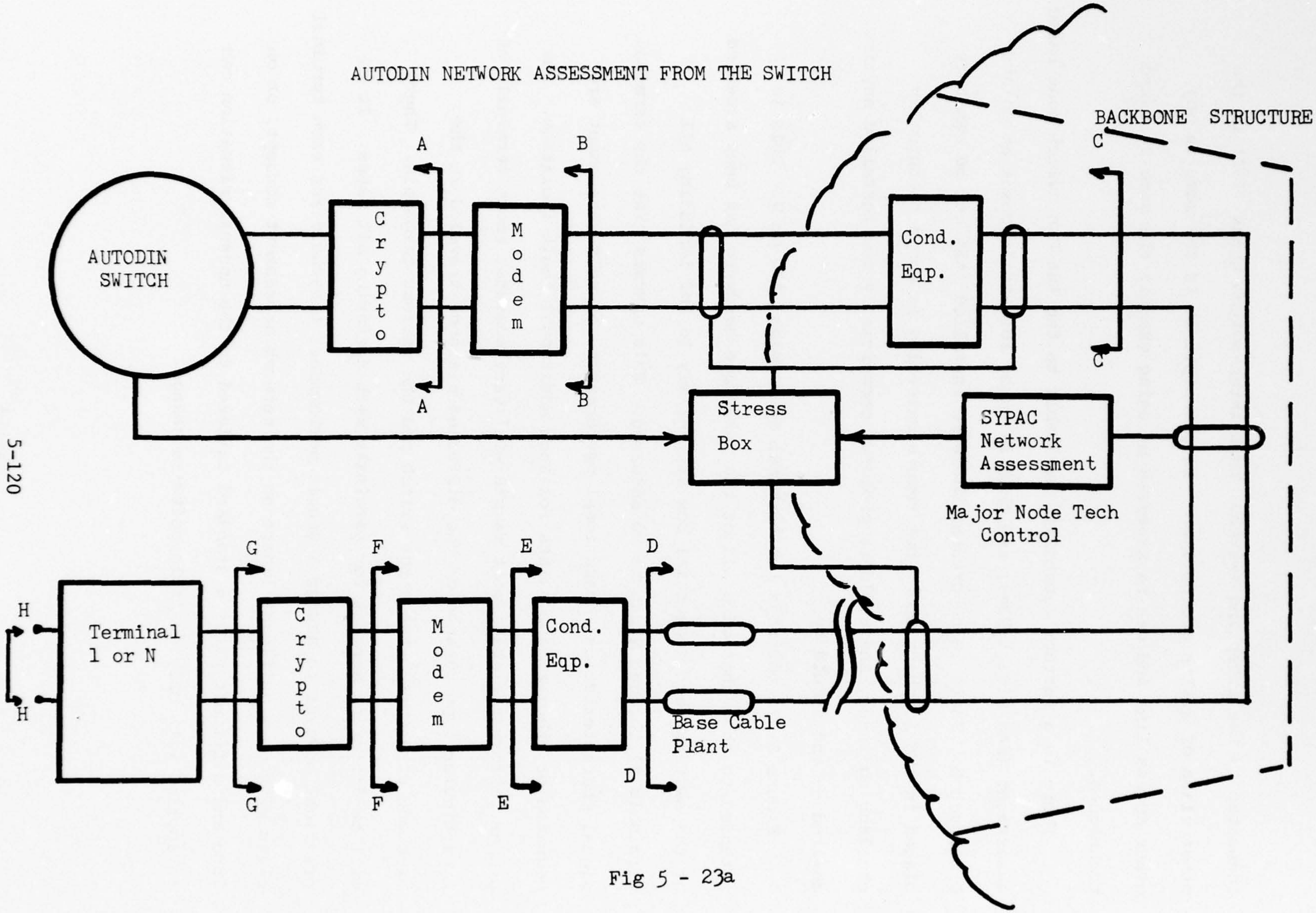
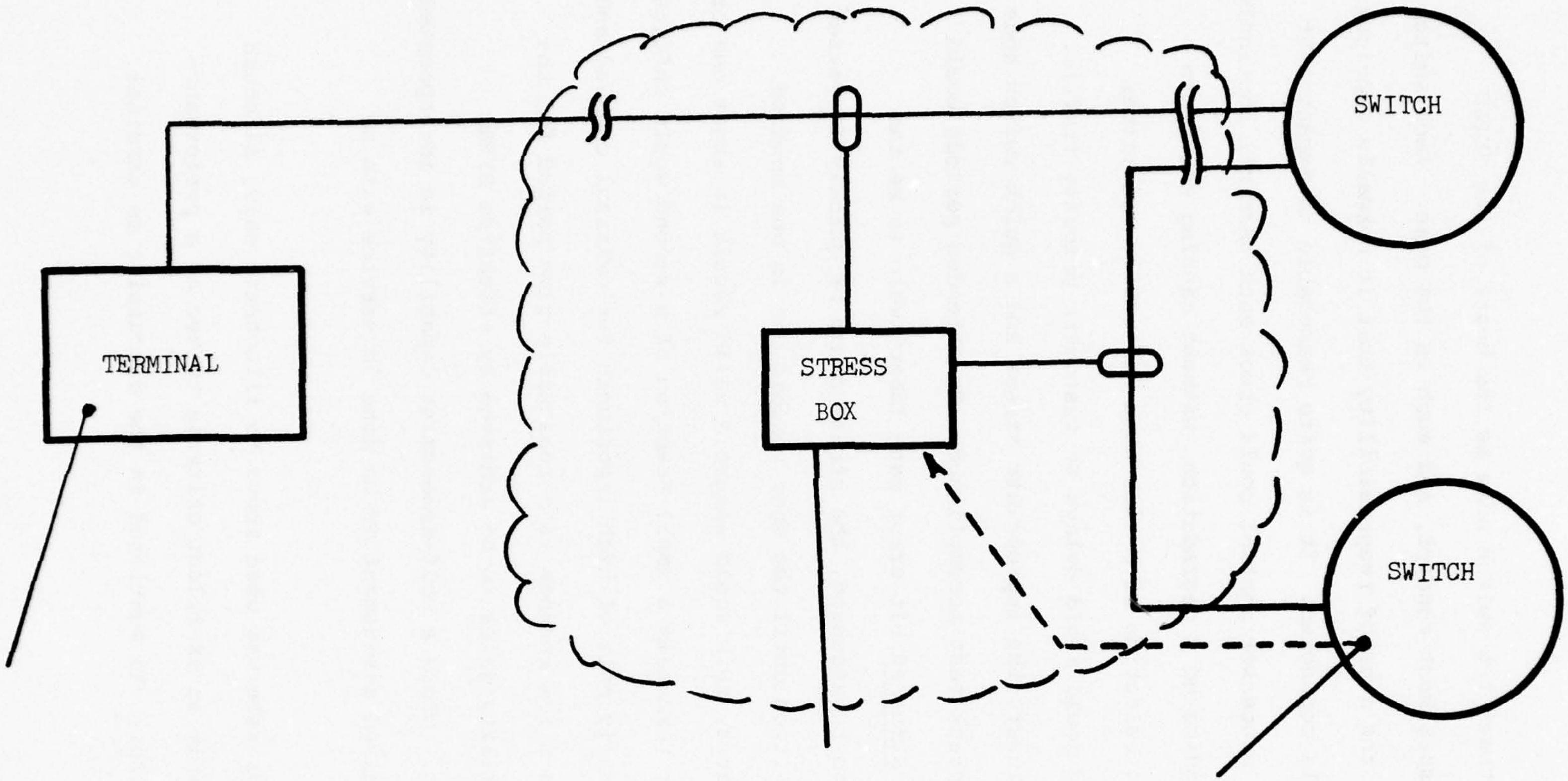


Fig 5 - 23a

Figure 5-23a portrays the switch node as the heart of the SYPAC network performance assessment concept, and such is the case. Each switch node will be assigned the area of responsibility that it normally services, including all terminals connected. It is quite reasonable to expect that a normal switch under processor control could check each terminal routinely and whenever SYPAC indicated a degradation, without causing delays to messages. Judicious selection of a time when no traffic was either being sent or received could avoid delays to customers priority traffic. The Stress Box would insert the appropriate stress and a quick switch node remote controlled loopback test accomplished. No extended periods would be required since, if <u>stressed</u> bit error rate (sber) were to be the critical degradation to be assessed, the stress could be quickly increased from an unstressed position until the sber reached one in one hundred. Even at slowest bit rates, this would assure a valid result in about one or two seconds. For most terminals a small fraction of a second would suffice. However, speed is normally only of high importance for critical command and control customers, and a few seconds is a reasonable time period for the performance and reliability gains to be achieved by effective SYPAC performance assessment. Where a self-assessment capability is incorporated or appliqued, the stressed assessment can be done in service with no customer awareness.

Stressed bit error rate was used above to illustrate only, although stressed ber is certainly an excellent criteria to use as a performance assessment. (Fig. 5-23b.) As mentioned in the discussion on terminal

IN-SERVICE NETWORK ASSESSMENT



Auto-equalization Voltage
Jitter
Terminal Sync Distress/Resets
ARQ Occurances
Stressed Bit Effort Rate
Errors Received and Corrected
Crypto Resets
Integral Performance Assessment

Jitter
Terminal Sync Distress/Resets
Signal Distortion
Channel Signal to Noise
(most terminals)
Crypto Resets
Remote Integral Performance
Assessment

Jitter
Modem Sync Distress/Resets
ARQ Occurances
Errors Received/Corrected
Stressed Bit Error Rate
Crypto Resets

Fig. 5 - 23b

self-assessment, the Stress Box will be predominantly a calibrated noise introduction box, but other stresses such as distorted amplitude and phase delay will be incorporated for the higher speed data devices and will be helpful in assessing performance margin. Other features such as phase jitter, frequency offset or other normally encountered environmental factors may be needed.

Each switch node will check all terminals, and concomitantly will assess the circuit, the pertinent backbone structure, the tail path, the base cable plant, the jack fields, and all other serial elements. The results of these checks disclose the status of that portion of the network assigned to that switch. This user to user assessment is synergistically useful in a total system sense of great value. More on this later in the chapter. A similar area assessment will, of course, be made by all switches. For purposes of SYPAC, a data concentrator of any reasonable size can be classed as a small switch, if the concentrator can assume or be modified to accomplish the connected terminal assessments.

It is also clear that once each switch has checked its area, it then must perform similar checks on all interswitch trunks, including all serial hardware, plus the many cable frames, cables, jack fields, etc. that populate all circuits in the DCS. The composite of the switch area checks and the interswitch trunk checks give the true status of the network -- from a hardware performance standpoint -- except for the switch itself.

No one should be content with the present software switch self checks now run by the switch. It is true that most of the processor error are

detected and brought to the attention of the operator and maintainer. It is the electro-mechanical part of the switch that now causes most troubles, including the cable frames, and wire junctions that are not presently checked. The comprehensive assessment will address most of them and will give a comprehensive portrayal never before available. The self-assessment and SYPAC signal analysis in service capability will clearly highlight the path along which troubles arise. The first and most important question will have been answered -- 'Is there a problem?'. Only if the assessment fails to indicate where the degraded condition exists will points A through H be used either manually or automatically to answer the question -- "Where is the problem?'. The mandatory feature for SYPAC network assessment clearly is the capability to work under the software control of the switch node in raising the stress to an arbitrary preset point so that SYPAC assessments will be precise and numerical.

There are approaches to preserve the technical accuracy of the loopback in those cases where the terminal in essence regenerates the signal in a loopback to the switch. The stress can be added on the send switch site before transmission and this accurately reflects the switch to the terminal performance margin; when in the receive side at the switch is representative of the terminal to switch direction margin. A loopback at H in a regenerating terminal is helpful, but not absolutely precise. However, as stated before, the terminals need a built-in self-stresser. Thus when the switch calls for a loopback at H, such loopback will be through the internal stresser at the terminal and the switch will stress the receive side at the switch. While no assessment conducted at a remote location

can ever be quite as precise as a fully instrumented local measurement, this loopback self-stressed measurement has to date been effective in detecting degraded conditions and central stressing is always illuminating.

As was covered in the section on Dedicated Broadcast Networks, there are several in-service sensing capabilities that will be required in SYPAC. These added sensors will permit corroboration of SYPAC signal performance assessment measurements. These real time readouts will include forward error corrector -- 'error corrected' pulses -- or other self-diagnostic capabilities. It will include, readout at the serving major node tech control, and the switch, of ARQ or other form of message repeat for error prevention. Resets of the crypto are indicators of problems, and crypto has analog indications of other circuit or hardware problems such as timing difficulty that can be made available. *Existing modems have indirect* indications of performance status, such as the 1800 Hz sync signal that appears when in trouble. Most modems indicate dropped synchronization by a light alarm, later models have auto-resync but still have drop/reset readout. The latest self-equalizing modems, such as the Codex have a voltage brought out to an alarm, but the source voltage is analog and can be used directly as a quantitative measure of the transmission stress between the modems.

The network assessment conducted from the switch major node, supplemented by corroborative in-service indications will increase greatly the likelihood of detecting problems and degradations. After all the boxes, terminals, cryptos, modems, etc., are implemented or retrofitted with the internal

sensors with suitable readouts, or multilevel digital alarms, the probability of anticipating problems will approach 100%.

Each of these added features will cost some money, but in most cases, the basic circuitry, from which the trouble indication is to be derived, is already present. The remaining cost for the kit and its installation is rather small and could be a field accomplished tech order change. Nevertheless, these costs even if they were rather high, would still be mandatory and cost effective in the context of minimum manning achievable and the still unchanged demand for premium communication services by the military.

There are a number of plans under consideration presently, to update or replace Autodin, and undoubtedly there will be other approaches examined as technology advances. The approaches are broadly divided into two categories:

a. The first is an update of the speed of the hardware, improvement to the software, and better and more flexible input/output devices. This upgrade will increase the capability of the Autodin network with no basic change to the mode of doing business. The ARQ may be altered, the processing of high priority messages may be improved, the security protection may be more sophisticated, but the operation will still be store and forward.

b. The second approach is much more dramatic and entails a complete new concept -- that of packet switching. The packet

switching approach can permit the customer to switch access mechanism to remain much the same as presently installed in Autodin and use packets only among switches or the packets can in essence start at the terminal and run through to the ultimate reader still in packet form, or all permutations in between. There is no way to predict what the DCS will ultimately select. The key issue in this study is not what form the 'New Autodin' will take but whether this SYPAC concept of network performance assessment will be suitable.

The SYPAC assessment concept is not based upon message length, but upon the performance margin of the hardware and the network as a whole above that for error free passage of bits. The stressing may not be identical with the ones suitable for present day modems and switches, but will be exact generic equivalents. The crypto handshake and the data cooperative interchange may be in principle the same. Therefore, it is clear that the SYPAC concept will undergo no principle changes, and in fact will have a rather simple task to stay current with the maximum changes that are possible in 'New Autodin'.

It is noted, however, packet switching will present the customer with a more robust appearing network and his packet will <u>initially</u> have a higher probability of successful transiting the structure. But this added flexibility will compound the O&M problems, and will in the long run cause severe operational problems, unless SYPAC is implemented for performance assessment of the whole network.

(2) Network Control

Traffic measurement in Autodin is a poorly developed technique if in fact it can be said to exist at all. During emergencies in a limited geographical area there is a measure of message limiting under a program called 'Minimize'. Under Minimize, routine and low priority messages are not filed for sending. Thus the network does not clog due to the additional emergency related messages. However, the network might be able to easily accommodate all the traffic if the true network status were known.

So far, the Autodin network in general has never really been loaded to even 25% of its full capacity. In fact, the theoretical maximum message load is not known except in broad terms. Few networks give much trouble when so lightly loaded. A question arises, however, as to what Autodin might do in a full emergency. It has been demonstrated many times that most DOD terminals are sized for peace time administrative traffic. It is likely that the network would stall in the switch/terminal mode. The network has a built-in priority system to assure priority routing through the net. Thus, the switch if all is operating correctly assures that high precedence messages are processed first. The remaining messages are placed in a queue awaiting a free period for forwarding or delivery. For a system the size of the DCS, this queue can build very rapidly. It is not desirable to have a large number of reels of tape full of messages scattered throughout the network, since most users believe that once the message has been delivered to the message center, delivery is assured quickly.

When the message flow is light, as it normally is, there is no real problem and the network loading can be ignored with little jeopardy to message delivery time. The real issue at discussion is what would happen if a full hostilities alert were declared, several fairly large scale brush wars were to ignite, or a near full scale war emerge. The message traffic would escalate rapidly and no control would be available except to 'Minimize' -- not altogether a very sophisticated solution to a very real problem.

One alternative would be to have these messages stored at the entry point for processing when delivery is assured, and with the customer aware of the hold. Another would be to allow the messages to enter and to slowly wend their way from switch to switch, building whatever queue is necessary at each switch, but again with the subscriber aware of the holding process. It would be possible to send the messages to a switch near the desired delivery point, by routes that avoid all heavily loaded switches serial for most high priority traffic, and hold these close to the desired end point.

There are of course a number of sophisticated approaches to address the problem, but all must be rejected for immediate implementation, because of the way the network was assembled, it has little capability to accept 'adequate' control. The only way to change anything of significance in Autodin is by 'Please' control. Please do this and please do that. Message centers have authority to shut off inputs as they arrive from the subscriber, but customers with their own terminals can do as they like, please or no. There is no way to selectively impose just enough controls to

to be sure that all messages flow freely. The controls are go/no go, and really are completely out of tune with the sophistication of the balance of the network.

Autodin was built for a logistics network; however, that is not the real reason for the lack of network control. The first, foremost, and absolutely indispensible prerequisite for control is information derived from sensors, installed at all the critical locations throughout the network to assess what portions are out of optimum operation and need correction. The second and equally needed element is the formulation of a control concept with both latitude and teeth. The latitude is needed so that the guidance and direction imposed upon the network can be matched to the needs. The present 'do nothing until a jam occurs' then 'slam the door on certain classes of users' is not adequate. The door must be closeable at a rate that keeps most users happy and that must include both high and lower priority users. This obviously requires a much more responsive management structure with the sensed information being centrally assembled and processed in practicable geographical regions, with net control responsibilities to oversee and direct the network. This clearly is the DCA in the case of the DCS. The network and all switch and terminal hardware must be designed and built with capability to accept control. Teeth are needed to be sure the controls really work, and are not another type of 'Please' approach.

It is quite feasible to build data terminals that incorporate overhead bits, and use the information contained in the overhead message to set internal control mechanisms. Controls of this sort could, in near real

time, reconfigure the terminal to accept for transmission, only certain classes of messages, or assign a prescribed number of bit or messages that could be accepted per hour or other time period. The net control direction could instruct the terminal to balk and alarm when a selected class of addresses is received. The terminal could be set by a control signal. The switch could give an "accepted, but will hold" signal to ease problems in certain geographical areas. The number of control concepts that can be devised is large and obviously can be highly varied.

The key issue, however, is very clear. There must be an absolute mechanism that controls the flow of traffic in the network to assure reasonable delivery of priority traffic, but all other need not stop. The control mechanism should have regulation at the point of entry, specifically at the terminal in addition to those instructions sent to the switch to govern switch response to changing environments and loading.

An equivalent key issue is clearly how to interconnect the control mechanism to the terminals. The SYPAC concept earlier outlined the manner in which the switch major node is to collect directly the self-assessment of the terminal and the in-service bridged signal analysis at major tech controls. A section on Orderwires covered the orderwire configuration to link terminals, and the manner of signaling to inform not only other terminals, but also the intervening tech controls of those events or status of communication importance. This orderwire obviously will not be busy full time, and will avail sufficient bit capacity to support almost any control scheme that can be devised. For example, if the terminal/modem is of

selectable speed, the subscriber can be alerted to make available the speed needed to clear a particularly long message or permit processing data to one terminal when another on the same base fails. This would help reduce the clog now requiring 'Minimize', and also reduce the need for duplicate terminals.

There is also considerable merit to such a combination of performance assessment and control signals. Terminals with degraded signals arriving at the switch can be alerted. If the subsequent fault isolation shows that the path between the terminal and the switch is defective, the terminal can be placed into a slower mode where the communication data transfer is acceptable. None of this should require maintenance personnel, or the clerical personnel who normally feed the machine, but have little technical grasp. The same procedure can follow if the terminal self-performance is degraded, the data rate can be adjusted downward until performance is acceptable, again with no one involved at the terminal site. There are other cases where centralized control is more than 'desirable', and is needed to assure the survival of the net itself. More will be said of this type of control in the satellite section.

c. <u>Autovon</u>

The Autovon network is a worldwide voice network, switched at a number of places in the world, providing interconnection among DOD agencies and a few selected organizations outside this military community. The switches are interconnected with numerous trunks of standard voice frequency

quality and use the standard 2600 cycle tone "on hook" and conventional signaling. Access to AUTOVON may be directly by four-wire subscribers or through an automatic or manual base exchange (PBX).

The AUTOVON network is the basic and single most important communications structure in the DOD. Even if this were not true a few years ago, the continual pressure to delete dedicated nets to achieve the apparent and sometimes actual savings by 'common user' logic, and the success in being assigned most other voice services has certainly assured such key status today. It is unlikely to change in the future. In fact, Autovon is now assuming the role of dial up alternating routing for many data services that would normally use a dedicated data circuit. Thus, it is very important that SYPAC address Autovon in an effective way.

(1) Network Performance Assessment

The Autovon switch is alleged to check itself. Like all highly sophisticated computers and processors, it does have much theoretical capability, but theory is of no use unless reduced to practice. The routines presently available give a first order approximation of the location of major problems within the processor and certain switch peripheral devices.

The Autovon switch has a card printer connected to the processor. The internal software examines the events witnessed by the switch, and then summarizes the incidents and prints a card giving reference data. This data was intended for use by maintenance technicians and was supposed to be

sufficiently unambiguous so that the corrective attention could be focused at the trouble site. This concept works to a degree. Hard failures on elements within the switch are fairly uniquely identified.

These built-in routines which print out a card format are not quantized but are a go/no-go. This criteria is not highly useful for determining trends or highlighting possible future difficulties. Many of the problems with the AUTOVON overseas network are related to the lack of ability of the switch to check all of its interfaces. Problems, such as broken wires on switch main frames, solder blobs, or wire chips that short or ground terminals and general deterioration of contacts and card connectors create, with time, an ever expanding set of failure possibilities.

The software routines give fairly clear indication of certain routinely faced problems such as 'dial pulses started but not completed'. This indication is classed only as fairly clear, since there are a number of causes of such symptoms. For example, most switch maintenance men construe this malfunction mode to be a circuit interruption while a call is in process of set up. From personal experience, the author knows of an equally likely cause, that of a subscriber dialing part of a phone number and then forgetting the last few digits. The switch indicates this problem before a subscriber can relook up the number and complete the dialing. The maintenance men presume the circuit failure cause and those who try to fault isolate the difficulty, of course, find no trouble. After a while, maintenance men get conditioned to ignore this printout.

When the 2600 Hz tone disappears at the switch indicating that a phone number is about to be dialed, but no bits arrive, the switch prints a card.

This situation always arises when a radio path fails. If, however, maintenance is being accomplished anywhere in the network so that the 2600 tone is momentarily broken in the PBX, or any serial element such as an echo suppressor malfunctions, the card punched is identical. The maintainer invariably, when questioned about this particular card printout, will blame the path dropout and then dispose of the card. Most of the time, when the author has pursued this trouble indication, the true cause has been located in maintenance related activities. The SYPAC channel assessment will monitor these same channels or others over the radio path and will have corroborative data to validate or disprove the propagation allegations Further, if there were fades on the path, trouble card printouts and full light up of the switch call board should result. This correlated approach is rarely used now. SYPAC can derive useful information from the switch and the path assessment data to assess that it is not backbone related and to initiate the search for the real location of the difficulty.

The switch in its myopic view of the network prints cards all day long and even on a quiet day produces a stack of 6 inches or more. Intelligent analysis on site is absolutely unattainable with the present printout software, the highly ambiguous nature of the indications. An admonition to start an analysis program is pointless and cannot be productive until some portions of SYPAC are implemented for correlative data and analysis capability. The worldwide procedure, used by site personnel is to riffle quickly through and pick out the two or three cards that indicate a standard problem for which a fix is well known. The rest of the cards are

pitched into the trash can, or into the pile to be centrally processed somewhere. This latter step is of less use to the network or to management than the prior one because managers are misled into believing that meaningful analysis is being conducted somewhere.

The above discussion is intended to point out to management that Autovon switch analysis is nearly entirely introverted and addresses the network in little if any practical way. Any future efforts on Autovon or on a new switch must make a major effort not to field again such feeble network trouble analysis software.

The Autovon switch has a series of register junctors. There are lights on the control panel which identify the register junctors when in use. It is a rather simple idea to sense each of these lights and ascertain that they blink during some particular given period. The traffic data collection system (TDCS) does this. Defective junctors may not be detectable by this method, since the circuitry automatically selects another which will accept a call, if a junctor is defective, even though this light momentarily goes 'on'. Further, the mere sampling of the junctor light gives no assurance that the call was processed correctly, but SYPAC can apply time duration light illumination to help resolve this difficulty. There are additional usage lights related to other functions within the switch which can similarly be brought out and processed to assure that the functions are operational as contrasted with merely on-off light operation. It would be a reasonable modification and much more effective to permit the switch to dial its own junctors in times of low switch usage, and put in either a degraded signal or a standard signal with quantized amounts

of suitable stressing. This looping of the switch on itself to check its noise immunity and degradation thresholds could give highly useful trendable performance data. This test could be run quickly, would be highly informative, and would avoid the simplistic data readouts such as mentioned above.

There are other specific tests that could be run, such as synthetically loading the switch to assure that the switch will still handle the rated number of calls. Combining this test with the stress test above would be doubly enlightening. The military development agency elected not to acquire this obvious and necessary piece of switch loading test equipment to 'save money' even though it was recommended by the switch contractor. There is no estimating how much this trivial R&D 'savings' has cost the services in added maintenance charges and degraded service.

The section of this report on the backbone structure, covered in detail how the status of the backbone major node to major node performance assessment was derived using measurements of the Autovon network interswitch trunks. ATEC has already demonstrated the SYPAC required capability to assess the interswitch trunks, measure the 2600 cycle tone level and frequency, the noise characteristics of the trunks, and most channel parameters of interest. Further, it is possible with minor changes in the 2600 Hz tone generation to use the 2600 Hz tone for measuring certain degradations in the backbone structure, such as, frequency offset, phase jitter, etc. There measures are, of course, made easily "in-service" (no disruption of any customer service). The proper summing of these IST

measurements produces the link performance number equivalent to the present DCA performance monitoring program.

Figure 5-24 is an example of an ATEC in-service non-interfering print-out and spectrum for an idle Autovon trunk. The signature clearly identifies an IST and needs no current data base, constantly validated to so recognize. It is easy to see the tone at 2600 and note above on the print out, FR indicates the frequency is specifically 2598 Hz. This is two Hz low. Assuming that the switch oscillators had been exactly 2600 this measurement would indicate a 2 Hz frequency offset. (The author has measured that these switch oscillators can accept and hold to within a few tenths Hz for this use, although the oscillators are ± 5 Hz as normally adjusted.) Note that WF indicates -53.7 dbmØ 3 KHz flat weighted noise. WN indicates -55.7 C msg. noise. Since the difference is 2 db it shows no significant spurious or cross talk tones in the channel pass band. The NF reading of 100 indicates that the predominant remaining noise is 100 Hz and this is the second harmonic of the prime power frequency. Close examination of the numbers printed in the spectrum plot indicate that there is an additional tone of about 850 cycles although it does not print with an asterisk since it does not exceed 60 dbmØ.

Figure 5-25 is a spectrum plot of that same channel a moment later. The 2600 Hz -- more precisely than 2598 -- has not changed frequency nor level. Both the 3 KHz and C message however have increased because of the presence of disturbing noise and a tone at 3100 Hz. The predominant noise frequency no longer is 100 Hz, although that tone still remains. Both of these above measurements were made in about 3 seconds and separated in

AUTOVON IN-SERVICE IST ASSESSMENT

AH WN-55.7 S 249/11Ø5 ØØ8

AV-2Ø.ØG FR+2598G WN-55.7AH SN+35.6AL WR-53.7 NF+Ø1ØØ

PA+ØØ.5 PI-19.5 VU-2Ø.Ø M5+ØØ.2 P5+ØØ.1

VU-2Ø.Ø PA+ØØ.5 SW+ØØ71 FR+2598 M5+ØØ.2

```
SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -6Ø.Ø
 Ø2 -65.8
 Ø3 -7Ø.4
 Ø4 -7Ø.4
 Ø5 -67.3
 Ø6 -64.7
 Ø7 -65.1
 Ø8 -62.9
 Ø9 -62.9
 1Ø -65.Ø
 11 -67.4
 12 -67.7
 13 -64.7
 14 -65.6
 15 -67.5
 16 -66.3
 17 -64.Ø
 18 -66.8
 19 -68.6
 2Ø -67.7
 21 -68.7
 22 -68.4
 23 -67.9
 24 -63.8
 25 -25.8******************
 26 -2Ø.Ø********************
 27 -26.4*****************
 28 -63.8
 29 -68.Ø
 3Ø -68.4
 31 -69.7
 32 -7Ø.3
 33 -69.5
 34 -7Ø.4
```

Fig. 5-24

AUTOVON IN-SERVICE IST ASSESSMENT
CHANNEL DISTURBED

```
RH  WN-43.3 S  112/0742 006
AV-20.9G   FR+2603G   WN-43.3RH   SN+22.4RL   VF-43.0      NF+3100
VU-20.8 PA+01.7 SW+0083 FR+2603 M5+00.4

SPECTRUM 6----5----4----3----2----1----0----1
 01  -64.1
 02 -64.8
 03  -62.4
 04 /62.5
 05 -59.7*
 06 -58.5*
 07 -58.0**
 08 -57.6**
 09 -57.0**
 10 -59.1*
 11 -58.8*
 12 -58.0*
 13 -57.6**
 14 -57.6**
 15 -58.2*
 16 -57.6**
 17 -57.4**
 18 -56.7**
 19 -57.4**
 20 -58.0**
 21 -57.3**
 22 -56.5**
 23 -56.7**
 24 -54.6***
 25 -27.3*****************
 26 -20.9*********************
 27 -26.6*****************
 28 -55.8***
 29 -55.5***
 30 -48.3******
 31 -43.2********
 32 -46.6*******
 33 -55.5***
 34 -61.5
```

Fig. 5 - 25

time 20 or 30 seconds, and so indicate the difficulty in expecting manual tech controls to identify and isolate the source of this crosstalk tone and noise. The ATEC instrument had no difficulty in catching the problem and making a hard copy print out for using operator and maintainer personnel. It is a trivial extension of this IST evaluation to measure the noise to the base exchange be it manual or automatic by assessing one or more switch IST interconnections. The SYPAC tech control sensor can assess through the switch to selected terminated pairs within the base cable plant to assess the cable plant's suitability and conditioning. ATEC already has demonstrated both of these capabilities. SYPAC can measure as many of the specific or high priority users' phone lines as is deemed economically feasible merely by internal programming. This assures that the connective structure is acceptable user to user, including the series of boxes and devices on these access lines used to interface and work through the Autovon network.

Another major category of SYPAC network check is quite similar in both concept and general approach to the one previously discussed for Autodin. The details of the approach are changed because the device, the method of functioning of these devices, and the signals that flow through the network are quite different. The first and most basic difference is that in the Autodin net, the terminals can both talk and listen full time with no interference to the reverse path. To this date, no such flexible human customer has appeared. The voice subscriber is a transceiver. He can talk or he can listen. He cannot do both, although experience tends to expose his natural tendency to talk while he is supposed to be listening.

This bit of jest is not really of trivial impact, because on long paths, the echo suppressors have a hard time deciding what to do when both subscribers insist on talking. In fact, echo suppressors are one of the troublesome elements on many transoceanic paths and the chopped up speech received is the result of both speakers talking, defective or malaligned suppressors, or all three. If voice paths were 4 wire -- both a send and a receive side end to end -- echo suppressors would not be needed. As of yet there is no developed hardware to remotely assess echo suppressors, but there could be. Fortunately, they are colocated with the switches in the DCS overseas and can be checked locally -- a number were malaligned when checked by the author.

Another of these troublesome interface devices is the Single Frequency unit (57). There are tests that can be run quickly that identify several classes of SF degradations or failures. Sensitivity checks are quite easy and are obviously required since out of 15 recently tested, none met specs of -38dbmØ. Most were 5 to 6 db desensitized. Two were more than 12 db degraded, and one was completely inoperative. Further, even good SF units malfunctioned when high level tones are present in the supposedly unused portion of the idle voice channel or when the basic 2600 tone is too strong. High level crosstalk or dialing tones are capable of precluding periodically proper operation of the SF devices. The SF units are ubiquitous and as a result draw little attention and no assessment. They are replaced as an entity such as a resistor or capacitor, after failure is noted. However, none of the above described 15 degraded

and broken units had yet to be noted.

There is some recognition of the general use of the SF unit, but little network grasp of the rather sophisticated function performed, and even less grasp of the network induced problems when these units degrade. Already developed simple SF unit assessments can be conducted from the switch major node tech control to evaluate both of the SF units on the switch to switch and switch to PBX circuits. Under SYPAC, centralized checking of the Autovon switch serving area including the connected base PBXs will be assigned to the major node switch, following the same concept as in Autodin.

Not shown on Figure 5-26 is the 4 wire subscriber. This important customer is handled much like a PBX access line. There is one difference however. There is little concern and no repercussions when a test is run to a manual base PBX since operators are used to this testing activity. If it is an automatic base exchange, tests disturb no one and no problem arises since the test is automated. A 4 wire subscriber is always an important one. Command posts, like base operators, do not get exercised upon reception of a test call, but Generals always respond poorly and so presently special procedures must be designed to run all tests and assessments during the night. In SYPAC, a special loopback capability must be installed to preclude test rings or other non-operational signaling and still provide the switch the needed loopback performance assessment capability. Several techniques are commercially available for such purposes and need only be selected and implemented.

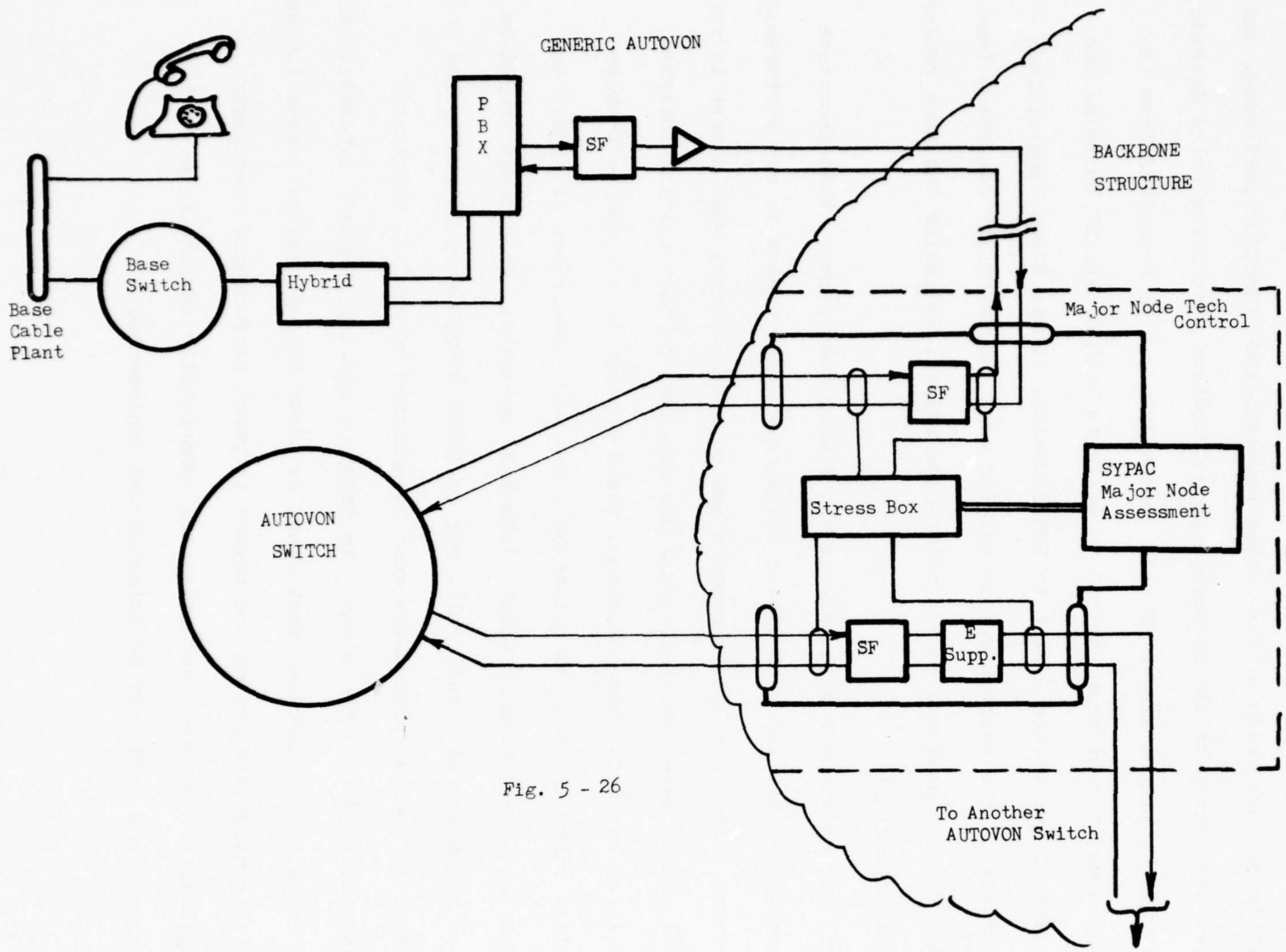

GENERIC AUTOVON
P
B
X
SF
Base
Switch
Hybrid
Base
Cable
Plant
BACKBONE
STRUCTURE
Major Node Tech
Control
SF
Stress Box
SYPAC
Major Node
Assessment
AUTOVON
SWITCH
SF
E
Supp.
To Another
AUTOVON Switch

Fig. 5 - 26

Again referring to Figure 5-26, each 4 wire line from the Autovon switch to the PBX or APBX is eventually converted to a 2 wire configuration by a hybrid before connection to the base telephones. The hybrid is normally a passive device, so when properly installed should have little change in performance with time. Tests in the field were conducted from the switch node tech control technically in accordance with the SYPAC switch/major node focused assessment concept.

Several interesting facts emerged as a result of observation of the hybrid remote tests. There was a general lack of understanding of how to make hybrid return loss measurements. More important to successful network operation was the lack of comprehension of the problems a defective hybrid could introduce. One hybrid had the signal sent from the switch to the hybrid receive port, returning to the switch less than 10 db down. None of the hybrids met published specifications in actual service use and this condition compounds the problems with echo suppressors. The cause may have been an unbalanced line, improper hybrid installation or a failure of the hybrid, but the performance assessment has answered the question "Is there a problem?". The second question, "Where is the problem?" is also answered clearly. A 2 db change in characteristics is a reasonable threshold to initiate corrective action.

There are also amplifiers, pads, and bridges in the various Autovon interswitch and access lines. These are all amenable to centralized checking from the area switch. The degradation symptom for amplifiers is increased noise or greater harmonic distortion. Level changes are

normally man-induced but are easy to check centrally. Pads and bridges failure or degradation mode is by adding noise. Cross talk anywhere in the miscellaneous devices in an access line or interswitch trunk is easy to detect by the assessments described. It is not always straight forward to immediately identify the entry point, but the SYPAC assessment concept approach will give assessment data and in a comprehensive form so that reasoned and substantiated analysis can be performed automatically and supplemented manually. It will be possible to clean up the total network and so this tedious work will diminish with time.

The general problem of troublesome switch supportive peripheral boxes and the difficulty in isolating the offending box was recognized by several on site personnel some time ago in Europe, and they developed a special switch software program called a test card deck. There is a separate test deck for each PBX connected to the switch. Using the capability provided in the switch software when the test deck is operative, a specific 4-wire circuit can be called up and held for test. The ability to freeze a specific set of hardware permits maintenance men to address a stable configuration.

The use of the test deck as one step in a routine periodic performance assessment has not yet been envisaged by field personnel who used it only after something broke. The expansion of the test deck to include assessment of more than the 4-wire portion had not been envisaged but ATEC capabilities to perform many of the needed tests automatically has already been demonstrated. Clearly, the SYPAC concept will include the expanded test deck capability as a necessary requisite in any future network whether

voice, data or hybrid.

There is one more area of concern, that of the base telephone structure. The base telephone network is capable of independent operation, although frequently of inferior quality. The cable plants are noisy, primarily because of human malwiring and poor installation practices, noisy pads, defective lightening protection blocks, etc. The cable plant will be checked from the major node tech control as part of the total network assessment by SYPAC. The base must be viewed as the input/output port of the connective tissue of the total system. This assessment does not require physical transgression of the main frame DCA/O&M boundary, but does electronically encompass the user to user on base portion.

The telephones are the terminals for Autovon and are part of that network. The fact that they have to be assessed is a surprise to most people. In Bell or other telephone networks, the customers are assigned the fault detection action. The base telephone system works the same way, and little harm is done if a phone malfunctions; there is normally one on a nearby desk. If the phone is isolated or emergency messages must be processed, such as fire or security reports, then full assessment would be beneficial. Command and control phones, etc., all need assessments. The fact that a telephone rarely fails, lulls maintainers and managers into a false sense of security. The rotary dial on the standard telephone has a small governor that controls the speed and dial pulse length. If these get out of tolerance, the phone gets wrong number, or 'idiot' recordings when the switch cannot sort out the pulses in accordance with the pre-programmed software. During one trip, the telephone service on one command

HQ base was barely acceptable, but the service off base through Autovon was very bad. Calls made from one phone to another base several hundred miles away always mal-dialed -- 15 times straight. By forcing the mechanical dial backwards to pulse faster, the calls could be accepted by Autovon and processed. This malfunctioning dial had been present for some time but no one either complained or asked for a new phone. Rather, they were mumbling to themselves and redialing many times to place calls. This particular phone was in one of the organizations that was examining why Autovon failed to work well. This problem should have been detected either by portable test equipment at the switch, or checked on the switch maintenance test board. However, no one was checking with either piece of test equipment because the phone 'normally' does not cause trouble. Second, the portable and test board test equipment differed rather widely in calibration so that had they been used, it is problematic whether the situation would have been better or worse.

The following example is not intended to belittle the well motivated efforts that take place piecemeal to improve Autovon service, but to emphasize as strongly as possible the need for a complete, comprehensive, total network performance assessment. The presumption that every box no matter how simple is degrading is the only safe one. Experience has demonstrated that where 'good' quality equipment has been delivered to the field, significant degradation are observed in about 12 to 18 months. The more likely case is where barely acceptable hardware is procured and the degradations due to poor workmanship or cheap contractor design approach

start about the time test and acceptance completes, if not sooner.

Unless this poor quality is formally recognized and added expenses are authorized in the way of added assessments and increased manpower attention, these devices will always be degraded severely, and the subsystem performance of which they are a part must always be deteriorated. Cheap equipment is always expensive!

In attempting to pull Autovon together and make it play well as a network, management has routinely sought simple answers, a single change or procedure that will fix the network. There have been a number of teams formulated to work on fragmentary problems, in an attempt to find 'the' cause of the problem. Each team found problems, each group made recommendations and each activity acted generally independently from all others. There was no centralized technical direction nor focalized analysis.

These partial efforts will always be relatively ineffective since every problem must be found and fixed, if premium Autovon performance is to result. <u>Further,a problem once fixed will not stay corrected, but will have to be assessed on a continuing basis</u>. Until this simple but absolute fact is recognized and more importantly reflected in all operational and management activity, marginal Autovon performance must be the obvious inviolable and logical result.

It takes considerable effort and system insight to isolate these problems and the military have few such people and very few on site. AFCS created the position of site engineer at major switch nodes and authorized a graduate engineer for the slot. These young officers had made some

progress in developing their system grasp and in training personnel to a higher level of analysis and fault isolation capability. Some of these slots have been deleted during personnel cutbacks. Some have been filled by personnel who are non-engineers and who are assigned to provide 'management'. This removal of technical leadership was a very poor decision. 'Management" always fails when the skills needed to do the job are not present. The 3055 military engineer was not assigned to optimize the output from the assigned talent. Rather, his mission was to lead an intensive effort into areas where there was no present capability and to create a systems analysis and fault isolation capability where none existed. Even with the loss or substitution of most of the site engineers, progress has been made by the remaining 3055's, but far short of what is needed in Autovon, and little progress has been made in the other networks.

There is one wide-spread fiction that adversely biases managers and technicians alike. Most networks represent a sizeable hardware complex. This hardware complex is heir to all the ills that always plague any electro-mechanical entity. There is recognition that the hardware associated with the backbone structure has maintenance, adjustment, and operating problems. With logic that is faulty, many people, and a large number of communicators, somehow believe that the hardware associated with each network although selected, procured, installed, operated, and maintained under policies and procedures that are common to both the backbone structure and network portions of system, somehow works better than the hardware in the backbone structure.

Every test, every measurement made in any Scope Creek or TEP type characterization has always found the network hardware at least as degraded as the backbone portion of the network. In many assessments since 1970, the network hardware has been far worse. Obviously, network hardware performance assessment must be a major, if not the prime concern, in network management. Certainly until the network hardware has been brought up to the generally 'improved' level of performance of the backbone structure, the network attention must be heavily addressed to the hardware aspects of network operations. (Superficial, misleading, and sub-element switch efficiency reports not withstanding.)

Surely, the DOD will attempt to improve on the performance record Autovon has provided. Truthfully, it is not too bad considering all the problems introduced by the initial procurement shortcuts, the installation induced difficulties, the operating and maintenance shortcomings, and the lack of management competence to direct network operations. Nevertheless, many changes will have to be made to the net before the voice network can be fully satisfactory for DOD. One obvious fact, the introduction of a new switch, even the TTC-39, will not solve the voice network problems. Much, much more is entailed, and the above sections highlighted many of the items of pertinence. A total voice network must be considered and designed -- even if incrementally implemented and the test and acceptance must be comprehensive. But of most importance a complete and in depth continuing performance assessment program must be created, implemented, and carefully managed. Then and only then will acceptable voice service result.

(2) Network Control

Autovon, like Autodin, has too little in the way of traffic control. Like Autodin, there is a priority mechanism that allows a higher precedence call to interrupt any in progress call and to process through the network until completed or until it itself is disrupted by an even higher priority call. This priority approach does assure, under most conditions, completion of the highest priority calls, presumably the most important calls. The software mechanism, used to implement this prioritization appears at first glance to be quite ideal. On deeper thought, however, there is reason to question the specific approach selected. A simple example will illustrate the problem. This example is not intended to belittle anything done with the existing Autovon network. The Autovon switches were procured much too early for DOD to have incorporated any of the systems/network thought that flowed from TEP measurements, subsequent test and analysis programs and the performance assessment efforts. The R&D agency that bought the Autovon switch never examined the system, rather they accepted generalized requirements contracted for and procured a switch. The acceptance tests conducted on the switch were far from adequate, and the many problems that have arisen since installation, fully document the less than systems integrity that resulted from the insertion of a well designed commercial switch in the middle of a military communication backbone structure, and interconnected to the normal assortment of military bases and special DOD customers. Some of the results could have been anticipated had any one contemplated the total system problem. The

obvious fact that the switch required higher quality lines than could be provided by the then existing military structure was pointed out by HQ USAF to both the switch development agency and the DCA. The development agency took no recognition of the problem based upon their view of their procurement charter. The Air Force started and DCA sponsored the Scope Creek O&M Measurement Program. Its progeny have raised the average backbone structure performance nearly 10 db -- ten times less noise -- so that the switch normally works, most of the time, fairly well, for most users, for not too demanding needs. See Fig. 4-8.

The problem was made worse in a number of cases by the procurement agency cost savings decisions that in both foresight and hindsight should have been recognized as life cycle cost multipliers of major proportions. Switch stressing and call insertion test equipment were deleted. An effective interswitch trunk routiner was rejected in favor of an older and cheaper but unsuitable device, etc. The switch, nevertheless, is a sound device of reliability and quality, albeit procured to specifications not in consonance with field needs.

The lack of systems grasp has another effect. There were few network control features provided. This is not really too surprising; the procuring agency asked for none, since it was only to buy a switch cheaply. The Autovon contractor bid to the procurement specifications and although he suggested several improvements, including a modicum of control, all were rejected for cost reasons. Thus, there is little built-in control and few provisions for effective real time direction available. Even with the above control picture, the fact that Autovon is a stored program switch

means that there are changes that can be made to improve the situation even now.

This SYPAC study is not intended to be a 'fix it' effort for existing hardware, but lessons experienced are not of benefit unless they are also lessons learned and examined for basic principles involved -- and there are many lessons to learn from Autovon.

A simple example will illustrate one of the techniques that is presently used to accommodate a commercial switch to military use in the absence of a reasonable control scheme. Visualize the Autovon multi-switch network overseas with too few trunks to the states -- to save money of course. This network has in use Routine, Priority, and Immediate calls threading their way to a switch and continuing over interswitch trunks. If the calls cover several hundred miles, several switches and several interswitch trunks are serially disposed to complete the call. If lightly loaded facilities are available so that the switch can process the calls and adequate trunks are available to desired locations, no one is unhappy and all calls activate as desired. The problem arises very quickly when all trunks are filled. Remember, some are filled with low priority calls, some by higher. Some of the trunks have calls extending through several switches, so that any interswitch trunk may be but one section of a much longer connection. When the serving switch receives and processes a high priority call, it disturbs or preempts an already set up call if the trunk is needed. If this preempted call went through several switches, considerable network time will have been lost, since all the calls disrupted will have to

be reprocessed again. If the priority call is for the states, the initial switch will attempt to go to the software designated primary switch to see whether there is a vacant trunk to the states. If there is not, a secondary designate switch will be tried. These first two attempts do not preempt but merely examine the situation and if the call goes through, no ill is done except to any call disrupted from the PBX to the entry switch. If the call fails to find a free trunk then it returns to the primary switch and preempts a call of lower priority. If there are none of lower priority it returns to the secondary designate switch and preempts any lower priority call there. If none exist, the procedure is terminated and the call must be reinitiated. If either the primary or secondary switch preempt an already established call, the effects ripple through 2 or more switches and several trunk groups.

The sequence of events can be quickly summarized by stating that Routine calls have to be processed many times in order to get a call completion and have zero chance for an overseas call. Priority calls disrupt many routine calls, but likewise have little change for a successful overseas call. Immediate calls disrupt both routine and priority calls and have only a fair likelihood of holding an in-region call for about 3 to 5 minutes before preemption, and little hope of an overseas call except at odd hours. Flash calls, of course, tear down lower priority calls. And have a good chance of an overseas completion, although even then some Flash calls are disrupted or preempted. Each level of priority causes trouble to all lower call. The important issue from a system standpoint, is that the overseas trunks are full for most of the day and all of the

primary duty day, with Flash and Immediate calls. Priority calls continue to disrupt routine calls, and yet after the resultant disruption have no chance to get an overseas trunk so the disturbance is both fruitless and pointless. The Immediate calls interrupt even more conversations with little chance of success. Repeated Immediate attempts succeed in ruining repeated calls without commensurate increase in successful call results.

All of this churning increases as detente fluxes, as political tensions shift, or as major reorganizations create issues that require phone calls. The larger the number of calls, the greater the disruption. This certainly cannot be the way a military system should work.

One conceptually simple approach could solve this problem. The network control under the SYPAC concept will know in real time the status of the trunks and will be able to surmise the likelihood of any priority level of call being completed to the dialed termination. If all overseas trunks are busy at Immediate or higher, there is nothing to be gained by having Priority calls, disrupting Routine calls on the way to the gateway switch, where it will stop. Software changes can result in an 'idiot recording' by the entry switch, informing the caller that there is no present chance of completion, based upon information fed to the switches by Net Control.

The proper way to control traffic is at or close to the source. This precludes loading any portion of the communication structure, when there is no hope of completing the connection. 4 wire subscribers normally have priority access some up to Flash, but even they need a switch control to be sure that they too are notified when their lower precedence calls will be

blocked. The operator initiated calls will be stopped manually and the 'idiot recording' will explain the situation to dial '8' customers. The alternate trunk route cancellation control now in Autovon can reduce the unnecessary and fruitless call teardown, but fails to address the real issue -- appropriate and timely action restricting only those customers required to assure acceptable service to the remaining suscribers.

There are a series of controls that are imposed by Bell even in their commercial structure to hold down the number of customers in the network, in particular times of stress. For example, if a major storm causes major property damage, including disruption to a significant portion of the telephone network in an area, subscribers all over the country attempt to call friends and relatives. Many of the calls cannot go through due to the damage, but people will continue to try and severe churning occurs, facilities are tied up in fruitless call attempts and little productive communications results. Bell has a mechanism they employ, that frees the functioning equipment in the damaged area. They place a one way restriction on calls to the troubled area imposed at all the switches even those far removed from the damage area. Customers are not told of the control, they just get a busy signal whenever they attempt to call a blocked area. Those people who still have phone service can initiate calls with no externally generated traffic clogging the routes out of the area. The hurricane that devastated Gulfport initiated such a one way freeze. A directionalization control concept is available to Autovon, but a full measure of near real time and more selective control must be embodied in any 'New Autovon' to make

the control imposed match the results desired.

The example using the blocking of the overseas trunks as limiting network performance is but one of a large group of complex issues.

The Autovon switches can accept several control capabilities such as 'trunk make busy' that narrows the input pipe from a location. This is normally a maintenance assist to be sure no one tries to use the trunk while maintenance or measurement activities are underway, but clearly it can be used for more sophisticated control when SYPAC is implemented. There is also a switch code cancellation available to permit denying calls for a particular switch -- but lack of traffic status in real time precludes most effective control actions.

The several control capabilities are generally implemented across the board on all switches and are not tailored to the actual magnitude of the network difficulties. They are called into action by DCA Control over an Autovon circuit. This obviously is a weak concept because failure of a small portion of the Autovon net access structure can isolate the whole network from DCA control.

There are literally hundreds of possible control actions that should be imposed upon the switched networks. The SYPAC performance assessment, in-service, traffic determination, supplemented by special sensing such as the Autovon Traffic Data Collection System, will give the necessary data inputs to correlate with information on the backbone structure to identify and isolate network problems. Much of this correlative analysis can be done within the SYPAC automated mechanism, but the final network decisions

must be made at the DCA area. Only there can all of the data be assembled and final traffic related decision made.

These control actions can be grouped under three general classes:

a. Hardware

b. Software

c. Traffic

The bulk of this study has been oriented to performance assessment and a large percentage of that has been directed toward assessment of the hardware elements in the backbone structure and in the various networks. Since all the Scope Creek and offspring special studies have proved that a major portion of the field problems relate to hardware malperformance, such exposure at length is warranted. Traffic matters are discussed in more detail later.

Decisions on network manipulations and traffic controls are not solely a technical matter. The performance of the hardware, of the backbone structure, of the terminals, and of the software is a prime consideration and may be overriding, but policy matters, special intelligence factors, special collection structures, and military tactical and strategic matters also heavily impact network and operational decisions. It is the SYPAC concern, however, to be sure that: all needed parameters are sensed and brought to appropriate locations for analysis and correlation; network status is forwarded to Area for operational and policy examination; operational direction and control is disseminated to all system elements required; selected parameters are sensed and returned to the controlling agency to

assure that the control was properly implemented and effective.

There is a further SYPAC concern; to be sure that all DCS hardware elements, including terminals, have suitable mechanisms and software incorporated capable of accepting any needed control.

Fig. 5-27 is a portrayal of SYPAC that outlines certain key functions of system assessment and control.

The unshaded area describes the O&M Agency responsibilities and covers the entire backbone structure, including the transmission media, the major nodes, nodes, tail paths, and the base interconnect structures . Integral to this backbone structure is the performance assessment of all of the hardware and the links, along with the processing through the orderwire structure for analysis and correlation of the sensed parameters at several levels throughout the hierarchy.

Also encompassed is the assessment of the hardware health of the terminals, the PBX/APBX, and the network switches. These parameters also are processed through the same orderwire/analysis mechanism used for the backbone structure.

The figure shows a lightly cross hatched area that depicts the network functions under the operational direction of DCA. This cross hatched area includes the terminals, the PBX, the network switches and analysis and correlation activities at Section, Area, and HQ. The three key network elements are not uniquely either O&M or DCA assigned, but have functions applicable to each.

The network sensing, control, and orderwires are displayed running

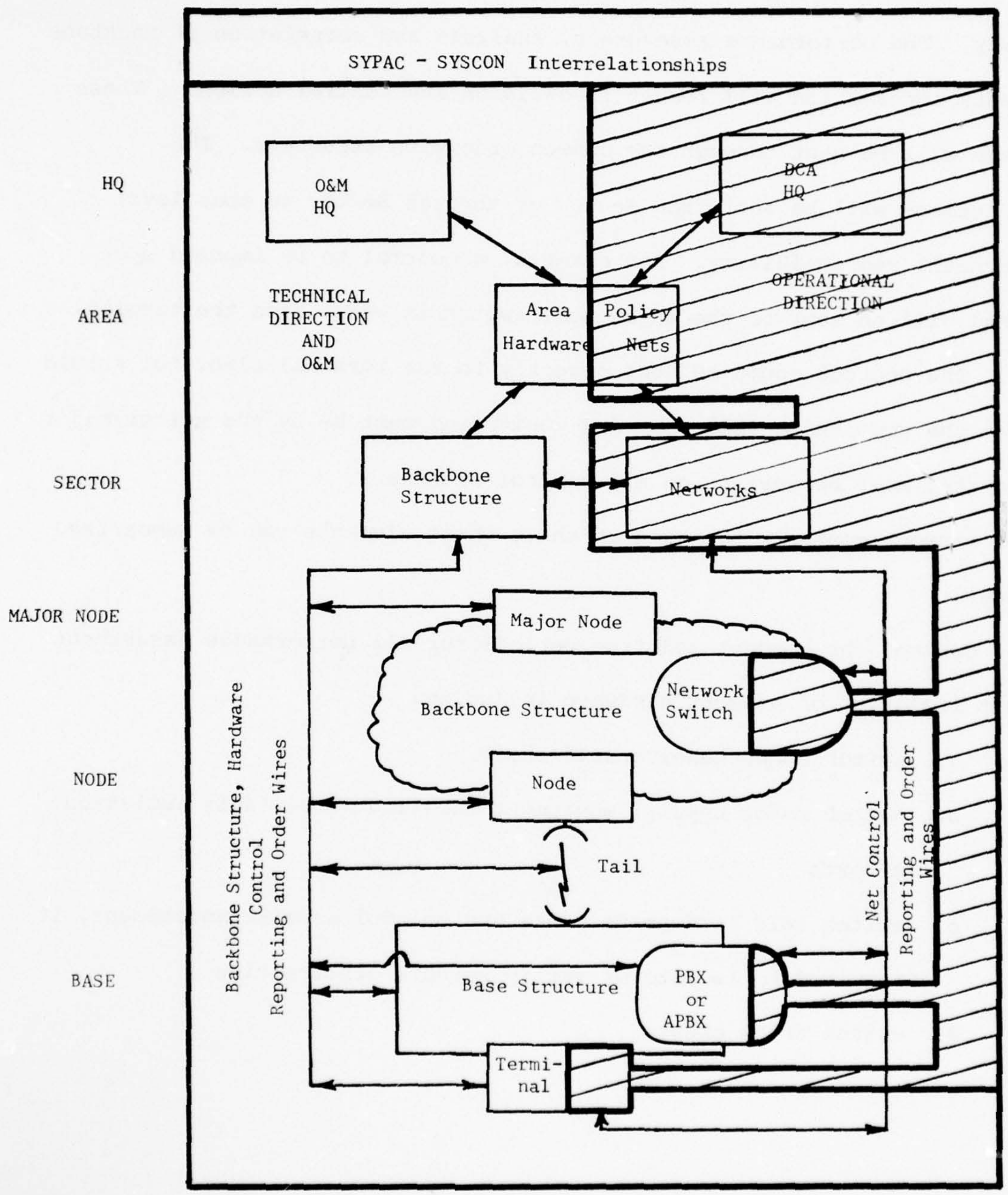

SYPAC - SYSCON Interrelationships
HQ
AREA
SECTOR
MAJOR NODE
NODE
BASE
O&M HQ
DCA HQ
TECHNICAL DIRECTION AND O&M
OPERATIONAL DIRECTION
Area Hardware
Policy Nets
Backbone Structure
Networks
Major Node
Network Switch
Backbone Structure
Node
Tail
Base Structure
PBX or APBX
Termi-nal
Backbone Structure, Hardware Control
Reporting and Order Wires
Net Control
Reporting and Order Wires

Fig 5 - 27

through the technical sensing, hardware uncrosshatched area. This is because the orderwires at all levels below Sector will be common and shared.

Further both the backbone structure and network orderwires are shown as two way. The performance assessment, analysis and correlation of backbone and network information will result in decision and control actions. These directions will be sent through the common orderwire structure. The control actions will be sent from Sector or through Sector to that level having overall responsibility. For example, a control to be imposed upon a terminal will be sent to the major node/switch in whose area the terminal resides. The control could be sent directly to the terminal also, but should not since the continuing follow-up and monitoring must be by the switch/major node, so they must be current on all control actions.

The network controls for each of these three elements can be summarized as follows:

1. Control the conduct and time periods for all performance assessment and fault isolation of network hardware including:

   a. switch comprehensive self-check

   b. switch major repair, equipment substitutions, fault isolation efforts

   c. switch self load assessments and control special assessment, if required to isolate or verify network difficulties

   d. switch trunk checks

e. satellite base exchanges assessments

f. satellite base cable plants assessments

g. terminal signal assessment.

2. Control the exercising and operational use of network software modification or entry including:

a. block message or call codes to selected facilities, remove communication loads from selected portions of the net for operational, exercise or maintenance purposes.

b. block codes and suitable 'idiot' message activation to prevent entry of communications that have negligible chance of completion.

c. near realtime software and route selection changes to relieve congestion, equipment malfunction or destruction.

d. institute a variable Minimize to accept calls for delivery off same switch, or off switches that can be reached over less than fully loaded trunk, and to accept all calls from priority one customers and calls above some real time variable communication threshold priority, etc.

3. Implement control of traffic by exercise of:

a. software activities covered above

b. control activation of additional trunks

c. call up satellite routes bypassing congested switches or regions

d. reconfigure the network by addition of new hardware, new RF routes and other near or non real time activities.

This study mentioned earlier that a major commercial company had completely misplanned facilities and grade of service because of poor installation quality, and the resultant erroneous traffic related data. A review of the Traffic Data Collection System (TDCS) summary of 69 elements indicates that about one third of the outputs have the possibility to provide false information if the basic hardware sensed is defective in one or more ways. An additional one third has a secondary error capability equally tied to hardware malperformance.

The conclusion of course is the same as that reached several places elsewhere in SYPAC. Hardware performance assessment to assure operation to at least an acceptable level is the mandatory first step, even for the present simple system control sensing.

For sake of emphasis, the simple, one-for-one insertion of the TTC-39s in lieu of the present Autovon switches even with such changes as 'out of band' signaling and other switch oriented actions may make the switch work better, but will have little relevance to the real operational need -- that of total network performance improvement and control unless all system/network matters are re-thought.

d. Satellites

Satellites are a new space age addition to the set of communication alternatives available for meeting the various operational needs of the world. It is unique in many ways that make it an immediate favorite of those who want quick and easy solutions to some difficult subscriber problems. It is unique in equally many ways that cause it to be troublesome and frustrating. It is at the same time more flexible and less adaptable operationally than the terrestrial facilities it supplements or replaces.

It was first put into operational use by the commercial world as a long microwave link. It also was implemented in a few places with multiple access points. The commercial multiple access concept, however, resembles multiple microwave links sharing a single geographical relay, or in this case a single space relay. As such, the commercial world uses the same type of circuit, trunk, or baseband access that is appropriate for any microwave link. The hardware control of the satellite ground elements is also the same as any ground link. The space segment hardware manipulations are similar to a large degree, including remote switching of hardware, changing selected operating conditions, and redirecting antennae, etc. The prime difference is that the space segment cannot be visited for repair. The military record of reliability is rather poor, and recently the commercial world has had their share of unreliability.

The satellite functions as applied by the military are divided into two general categories:

a. The first is a nearly identical role to that of a microwave link. The length of the path is very long in space and the ground spanned is routinely transoceanic or transcontinental distances. The entry and exit from the satellite terminal is by conventional tech control. The mission traffic is handled point to point like any trunk.

b. The second is a multiple access network where each customer has his own satellite terminal and uses the satellite as a relay point to rebroadcast to other users on the ground or in the air space covered by the satellite antennae. The coverage is area to area.

The SYPAC concept applies to satellites. The approach to the point to point and area to area application, of course, is quite different. In the case of the point to point mission, the satellite is a portion of the backbone structure. It has no network role, no switching activity, and few special considerations. The area to area activity has little conventional broadband trunking duty. Rather, it provides thin line interconnectivity among a number of geographically spread users. This satellite function, however, entails the operation of at least one, and in most cases, a number of networks. Both classes of satellite usage, nevertheless, can be accommodated by the application of suitable portions of SYPAC concepts covered earlier. Each category will be covered below separately.

(1) Satellite, Point to Point

(a) Performance Assessment

The point to point satellite is a one hop, long distance microwave link. It forms a part of the backbone structure, just as any microwave link. The individual channels are placed in a baseband that may be either a frequency division, or time division format, for transmission to a remote terminal. At the remote satellite terminal the whole baseband either may be entered into another broadband link for continued relay or broken down to the channels or groups levels that originally made up the composite signal. The channels that enter and exit the satellite link traverse a tech control. The tech controls at each end can apply the SYPAC performance assessment approach directly, exactly as described in the Backbone Structure and Network Assessment sections.

The satellite terminal is more complicated in some ways than a similar channel capacity microwave link. There is a complex satellite tracking antennae, the receivers normally have a parametric amplifier that helps compensate for the lower RF signal level received and the resultant much reduced performance margin, and the hardware placement makes maintenance activities less convenient. These all, however, are matters of degree, and do not change the basic maintainer skills nor the approach required.

Thus, the point to point satellite link can be performance assessed in principle as outlined previously. The fault isolation that inevitably derives from performance assessment is on occasions a bit more inferential.

For example, if the received channels start degrading, the cause may be at the send or the receive end just as in a microwave link, but, it may also be in the satellite itself. There is presently no direct way to measure the satellite performance, but there are a number of ways to indirectly infer the desired results. However, the first question, "Is there a problem?", can easily be determined by conventional performance assessment techniques. An in-service Noise Power Ratio (NPR) determination concept has been derived recently that can be implemented easily, and in such a manner that it has no impact on the satellite hardware or operational reliability and obviously it will have a positive effect on fault isolation.

Just as described earlier under networks, there is no need to remove a link from service in order to assess the performance. All technicians know what can be accomplished by use of a 1000Hz tone and appropriate test equipment. In the SYPAC era most of these same measurements and many more will be automatically and routinely made using the normal signals traversing the channels based upon known signature characterizations. Thus, the signature analysis and link data correlation conducted at the ends of the link will be able to make almost all fault isolations in-service.

In a few cases, a problem may be especially troublesome or intermittent, and it may be desirable to attack the fault isolation directly. In a previous section a stressed loopback test was described. The terminal used as an example was a rather small unsophisticated data terminal. The loopback for the terminal was expanded to include the modem and the crypto. There is no constraint as to where the single turn around occurs, so long as the interface at the loopback is suitable.

In the case of the satellite terminal, stressed loopback testing can be accomplished at the multiplex, the modulator, the Intermediate Frequencies (if there is one), the Radio Frequency (RF) transmitter/receive interface, RF looped in free space, or looped through the satellite. The terminal RF loopback may require a turnaround mixer, but it is technically easy. Each of these loopback points permits both performance assessment, and fault isolation and is useful to both operators and also to maintainers. In dualized satellite terminals most of the above listed loopbacks can in general be conducted while the node is still processing normal operational traffic. In one case of a satellite terminal, however, the hardware implementation was so poor that the loopback results were useless. The performance of the hardware was completely submerged below the uncontrolled cross talk noise and direct coupling within the cabling. All the measured loopback numbers, apparently very scientific, were useless.

(b) Control

All circuits that traverse the satellite link must pass through a tech control. This tech control not only has access to the circuit for performance assessment, but also has absolute jurisdiction over these circuits. The circuits can be managed, and if all else fails, the subscriber can be disconnected at the patch bays. Obviously, disruption of a circuit is the last resort, and used only when high levels in the channel cause cross talk for other customers, or where the channel is needed for a higher priority user. Any operationally needed control can be imposed with technical ease. This procedure is no different than that used presently

throughout the DCS and is emphasized here, only to contrast clearly with the technical control in the following Area satellite section.

For all point to point satellites, there is a satellite control function. This control is vested in a ground terminal with no responsibilities for actual communications. The control given to this location is for positioning the bird in the proper orbit, correcting any antennae aiming angle errors, substituting boxes within the bird when degradations are detected and regulating any variables that may have remote adjustments. They are properly called satellite control as contrasted with satellite communication control.

(c) <u>Orderwires</u>

The orderwire requirements for the satellite terminals are no different from any RF equipment site. The satellite structure requires a full time maintenance channel to the other satellite terminal. Each terminal must be connected also full time to the serving tech control. This latter orderwire, of course,must have both voice capabilities and self-assessment, alarm, etc, remoting provisions exactly like a well-engineered Microwave link. Certain satellite bird remote sensors and monitors must also be forwarded from the ground terminal to the serving tech control. In general, point to point satellite orderwires must parallel any large RF node requirement as covered in the backbone portion.

(2) Satellite, Area to Area

(a) Performance Assessment

The area satellite is a one hop user to user type service. In general, the interconnection is between two users and is thin in that only one channel is provided. This channel may be only a teletype circuit, it may be a standard voice interconnection, or it may be a data channel of rather high data rate, depending upon the terminal, the satellite, and the operation requirements. The connection between the users may be permanently netted and in full time usage, or may be established only when needed.

The connection may be among a set of users with a community of interest- a true network, or there can be several networks among several sets of users all traversing the satellite simultaneously.

Performance assessment in the area mission is different from that covered for the microwave and point to point structure. In those usages there are tech controls that have absolute jurisdiction and control of every circuit passing through the terminals to enter the satellite link. In the area case, there may be no tech control in series at any point. There is no central node anywhere on the ground in the area satellite structure.

Figure 5-28 shows a simplified layout. In this figure, subscriber A has set up a connection with A', and B with B'. As can be seen, the signal flow between A and A' and B and B' does not share any common ground node where tech control or performance assessment can be accomplished.

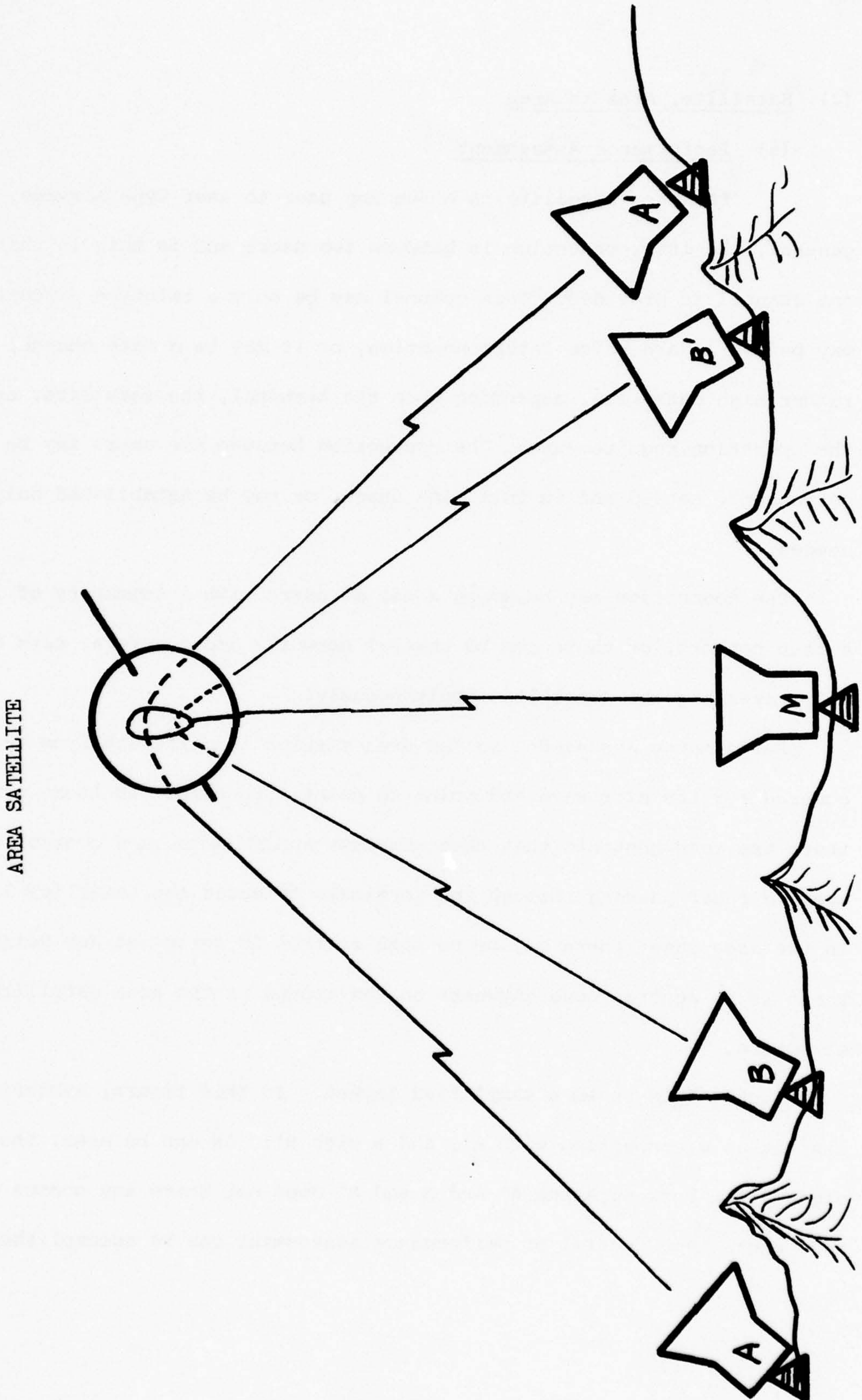


Fig. 5 - 28

The only common point is the satellite. From an operational standpoint, the satellite is the obvious place to assess and control this unique interconnect structure. From a practical viewpoint, personnel cannot be placed in orbit to manually manipulate the circuits. Early satellite developers failed to understand system needs, so failed to incorporate any provisions for any normal tech control activity. Even on later vintage satellites, the developers objected strenuously to any additional weight, added components, or the slightest increase in complexity. They stated that all added features above the basic receiver/transmitter reduce the reliability of the satellite. This, of course, is true, but such a half truth that it reflects a nearly total lack of system grasp. The opposite extreme from this simple transmitter/receiver only satellite would be a very sophisticated bird with all assessment, control and communications manipulation capabilities desired. The probability of failure is higher on the more complex satellite by an amount approximately related to the number of components. If 'technical reliability' were the entire story, then the least complex bird possible would be the best selection. But this simplistic approach fails to recognize that the requirement for the satellite in the first place is to meet an operational need. The entire satellite plus terminals complex must be optimized for <u>operational</u> reliability. Technical matters are a part of the overall mission dependability, but only a part.

For example, one of the earliest satellites had the simplistic transponder approach. It worked well as long as only a few people used the

bird at one time, as long as everyone accessed the satellite with only the approved power, as long as no unauthorized customers used the bird, as long as there were no inadvertent or overt interference or jamming efforts, and as long as terminals were properly maintained, etc. Early in the life of the satellite, there were few terminals and all users were well-known. There were excessive power accesses, but with only a few users, the offenders could be located, by exception if no other way. The unauthorized users were generally inadvertent violators and were laboriously eliminated one at a time, although this took a number of months each in several cases. Only in a few cases was the operational service unsatisfactory. These few cases, however, evidenced problems that were highly disruptive of all services attempting to transit the bird. The most widely known case was where a terminal overseas had hardware problems and was experiencing poor communications. The terminal operator attempted to solve his problems by transmitting more power than he was authorized. Since the power in the satellite was limited his excess usage robbed all other users and so all users had unsatisfactory operational service. The bird was reliable and operable, but, nevertheless, no one could use it. The presence of a technically reliable satellite is of no operational interest or utility if it cannot be used.

The ground terminals, much like its space subelement, are not well designed either for performance assessment of the signals it receives or transmits. The user terminals presently are normally procured as a

separate entity nearly devoid of any system or network considerations beyond the basic capability to send signals during test range type sterile conditions. Users also are intent on getting their terminals at lowest cost and until the total system aspects are evident, they will not recognize the need for performance assessment or control and the associated costs. These costs are as necessary as the cost of the antennae, the transmitter, or the receiver. For without all requisite elements the total network will not work when needed in times of stress or war, although it will appear to work well under peacetime low stress conditions. Presently, ground terminals have the obvious meters for transmitter output, but no way to be sure the space radiated power is related to the meter indication. The receivers have a noise figure meters, but do not measure all of the wave guide structure needed to make the figure meaningful and fail to measure, for example, the antennae and slow degradations in some of the wave guide components.

It should be self-evident that what is required for the satellite structure must be an optimum balance. It must incorporate only what is operationally needed for the wartime missions to minimize the technical penalty. This goal obviously precludes the simplest possible satellite technical implementation.

As displayed in Figure 5-28, a separate non-user terminal presently is placed somewhere within the area of coverage of the satellite. The

function of this terminal is to monitor the terminal retransmissions from the satellite. Only the retransmissions can be heard at the monitor, since all original signals aim into space at the satellite. Nevertheless, there is much that can be learned from monitoring these satellite retransmissions. In essence, the monitor hears the original signal as sent by the user and as amplified and processed by the satellite itself. If this resultant signal signature is appropriate in all respects, the performance assessed obviously is acceptable, and there is no problem. If the signal is deficient in some aspect, however, the monitor terminal (erroneously called a control station because it has no control) detects the degradation and initiates a special performance assessment. The monitor terminal is technically similar to the user terminals, except that it has a larger complement of conventional test instruments. These test devices are used to evaluate the satellite rebroadcast signal to surmise where the problem might reside. This monitor terminal has modems and other devices that are used by the various customers, so that the signals can be processed, as the intended user would do.

There is an additional capability, however, that is of use in performance assessment. The monitor terminal has a transmitter, again much like the users, that can generate signals of prescribed characteristics. The monitor station, knowing the features of its own transmitted signals can then measure the distortion or other form of degradation on the received

signal introduced by the satellite and by the two long space distances to and from the bird. This direct satellite signal observations permits accurate satellite evaluation and performance assessment.

If the satellite processes similar modem signals from the monitor terminal acceptably, then any operational problems must be in the user modem, the associated ground equipment or the user satellite terminal. Since some duality of devices exists, the troublesome element often can be found by substitution. In any event, the first question has been answered, 'Is there a problem?'. Since there may be several kinds of signals traversing the satellite, the monitor terminal must be prepared to generate, decode, or otherwise process and analyze all classes of signals.

(b) Control/Orderwire

For the area satellite, the orderwire and control element cannot be separated. Whenever there is a performance assessment less than standard, the monitor station must identify the user concerned and initiate corrective action. This attempt at user identification is far from trivial. If the coded user is using his assigned code, is on the correct frequency, is broadcasting at the assigned times, etc., the identification problem may not be too difficult. If the degradation is not serious and if the trouble disturbs no one else on the satellite, a little time spent in user identification does not cause operational difficulty. Presume, however, that the degradation is causing other subscribers problems, perhaps by high intermodulation or power robbing. Now the monitor station must first

identify the source of the trouble. If the user cannot be quickly ascertained, the satellite gives poor or no service to everyone. However, assume that the user is identified, the problem must be corrected. The user must first understand what corrective action is required -- assuming that the monitor station knows -- the subscriber must agree that such a change is desirable and that he has the mental and physical capability to accommodate the change. This approach may require extensive user operator knowledge and cooperation. Experience has shown that these may not always be present.

Integral in the above bland statements is the implicit assumption that the monitor station and the user were able to talk together. This last assumption is a very poor one. The DCS has never provided the proper orderwire structure. The research and development agencies rarely address system issues, and summarily reject any hard or complex issue based upon satellite reliability considerations. As a result, the first satellites had no effective orderwire mechanism at all. The later ones are little better although there is an orderwire that may be used if both parties are present and care to respond.

If the user agrees with the analysis, as portrayed by the monitor station, he may if he chooses comply. If he is unable, disinclined, or does not agree, he does not. There is no way to force even a serious discussion on the issue. Clearly, while performance assessment is perhaps marginal, there is no control at all. 'Please' control is too strong a description because there is no assurance that the culprit can even be

identified, or that he may be asked 'Please'. During the month of September, 1974, for example, over 50 authorized user violations were recorded.

Further, if an unauthorized user accesses the bird, there may be no way to identify him. Also, if he has his unique modem or transmitter, there may be no way to talk to him at all. The unauthorized user may not be a friendly and so would not be interested in any 'Please' suggestions even if he could converse with the monitor station. In the last analysis, the unauthorized access may be a jammer. The intent may be to disrupt communications. It is clear that all satellites to date cannot really be operationally useful, unless every other nation in the world permits it. <u>In this light, the argument about technical complexity assumes its rightful proportion -- of importance but certainly subservient to operational needs</u>.

The rights from a customer standpoint are to have access to his fair share of the power and bandwidth of the satellite and so have the capability to communicate at an acceptable performance level. The responsibilities associated with these communications rights incorporate the constraint not to disturb the rights of anyone else. What is needed, of course, is a control mechanism to assure that all users meet both rights and responsibility requirements. Practical space realities preclude installation in the satellite of full control over every activity, such as is exercised in the normal tech control, but some very necessary ones can be incorporated without unduly compromising the bird. Also, there are many controls that can be built into the user ground or airborne terminals. The composite of

the satellite plus the terminal controls can achieve a reasonable level of operational control.

Satellites are basically space relays and incorporate a receiver and a transmitter. If they both are 'wide open' and have no channelization, then any satellite controls exercised will generally effect equally all signals transiting to the satellite. The satellite spectrum must be channelized either in time or frequency as pertinent, then signals in one channel can be handled discretely from others. The power may be increased or decreased, or hard limited to reduce channel induced troubles or to provide added flexibility for other users. The channel may be blocked to deny it to an unauthorized customer or a jammer without disruption of other satellite users. This capability to manipulate the channels individually is not intended to be an awkward, slow, occasionally used feature. Rather, it must be a real time control action. For example, on the coded access users (for example, a frequency hop code), once the disruptive code is derived, that particular code could be 100% denied at the satellite without disrupting the other coded users accessing the same frequencies -- if the control capability had been created.

No satellite to date has considered jamming very seriously. In the future, special antennae, with narrow beams to avoid the jammer or disrupting signal, will require movable nulls, perhaps several. All of these features also require real time control, and a way to assess results of the antennae movements or null positioning. The real time performance assessment required to detect and quantify the basic trouble is obviously needed to see whether the selected corrective actions are

effective and to select among the possible alternatives to pick the most appropriate measures. Again as always, performance assessment is the prerequisite to any effective control.

The monitor station, as described earlier, sees only the signal sent from the earth station after processing by both the satellite receiver and the transmitter. During the above performance assessment and trouble minimization control actions it would be helpful, and may be mandatory, to view the received signal and to examine the effects of corrective actions without the effects of the satellite transmitter added. This is a capability that can be accomplished on board the bird, and the processed or sensed parameter transmitted by orderwire to the monitor/control station. The selection of either totally ground based or bird based assessment or the election of some hybrid form of assessment is an operational/technical tradeoff that relates capability, cost, and reliability. It must be emphasized that in the face of determined jamming clearly performance assessment and control are 'cheap' operationally, since without them the investment cost has no return at all. The unjammed reliability figures assume zero operational interest.

There are other techniques that can be applied to the satellite including on board processing of signals, error correctors for digital traffic, signal analyzers, spectral analyzers, etc. Each provides data that may be useful to analyze disturbing conditions and permit evaluation of corrective control actions. Each has a beneficial operational impact, a cost impulse, and technical and weight considerations. Some, however, are clearly needed in times of electronic or wartime stress and all require

an orderwire for access.

The SYPAC control of the user terminal will be much like that described earlier. The built-in performance assessment will inform the user of his in-service performance margin during normal operational use. The margin figure, bit error rate, or equivalent number will be sent along the orderwire. Thus, the monitor station will have performance assessment status information on all active terminals using the satellite. The area orderwire and terminals must be configured so that control signals can be sent from the monitor terminal to any terminal, directing selected accommodations, including internal switching to a different operating condition, or off as required. For most small terminals, the in-band orderwire/control can function on an effective operational and technical basis. For the first time this will give the satellite network a real control mechanism.

As previously mentioned, the area satellite service normally is configured in a series of separate subnetworks. Each subnet has in essence a net control station -- also a misnomer since it presently 'administers'. With the in-channel orderwire mechanism, the operational subnet control station can in fact assume some of the network control. The ability to control each terminal of each net, plus the ability to control the satellite and terminal hardware will assure control for the satellite as a whole when accessed by authorized users even if their access may be defective in some aspect.

There remains, however, the problem of technical management vs. operational needs. There must always be a method for a high priority

user to access the satellite even though the user terminal may be disturbing the balance of the users. There are times when the highest priority users can be permitted to disrupt lower priority users for a short period based solely on operational need and communication priority. However, in cases of a priority one user disrupting several equal priority users, the control terminal will have to take whatever action is required to protect the majority. Presently, the only viable alternative would be complete shutdown of the disruptive offender, although in theory his power could be reduced. This power reduction concept is excellent except there is no way to assess how well the intended receiving terminal now can decode the messages. With SYPAC real time, orderwire reported and internal self-assessment, the control terminal may be able to reduce power on the offender to a quite low amount and thereby limit the disturbance to other priority users, but still permit acceptable communications by the disrupter.

The above discussion has assumed only authorized users, with system integrated orderwires. Unauthorized users or jammers, of course, have no such capabilities. Consequently, these sources of signals have to be handled in a more direct way. The variety of signals that can be impinged upon the satellite is large. The full description of the protective control actions that can be taken by the monitoring and control terminal under SYPAC is highly dependent upon the capabilities built into the bird, and into the terminals. The more sophisticated the techniques built into the hardware the less disruptive to the normal communications will be the anti-jam

reactive controls and the better the protection from the jammer. The key matter,however, is the mandatory nature of the terminal performance assessment, distributed on the in-channel orderwire, the effectiveness of the anti-jam actions can be observed in real time by the control terminal. There is no need to overreact and deny all power, or access to important but lower priority users, if the high priority users can be provided acceptable service by some less drastic corrective action as ascertained by assessment in real time.

The salient issue in all discussions of network management and control, including specifically satellite subsystems, is the absolute and overriding necessity for terminals that assess themselves in normal use, and that provide information to the net control station and to the satellite monitoring and control station. <u>The superior mandatory requirement is that the control mechanism and the control terminals be as survivable electrically and operationally as the highest priority networks or weapons systems that they support</u>.

e. <u>Base Telecommunications</u>

As was stated earlier, the base cable plants frequently are the noisiest portion of a communication circuit. Lack of an on-base patch and test facility has made assessment, identification, and correction of a noisy cable plant tedious, although not difficult. But most Squadrons are content to react to local customer complaints, and blame the backbone structure for all problems on circuit that leave the base. The base induced noise may equal or exceed the degradation experienced on a DCS

circuit extending half way around the world.

The Air Force must be concerned with a large number of airbases and the base cable plants that interconnect all the base communication facilitites. These cable plants in some cases are relatively new and presumably are in good condition and might be expected to provide good noise free performance. Other bases have venerable cable plants and could be expected to be inferior in service. As seems to be usual in the communications world, precise measurements show very little connection between the age of the base cable plant and its performance, except very indirectly. Most problems with a cable plant can be classed into 3 categories:

a. cables that get wet

b. cables that get noisy

c. cables that pick up power line hum .

Administrators believe that these degradations come purely with age. Qualified personnel know better and recognize that in general cables get wet because of poor splices, poor installation or lack of proper pressurization. Cables get noisy because installers have scramble wound terminations, reversed ground and signal leads, and left bridged pairs unterminated. Cables pick up hum by wiring 60 cycle power intentionally or inadvertently through cable pairs or the prime power ground may be defective at one or more base facility and the power may elect to use the communication cable as the ground return. All of these are human introduced by acts of commission or omission and are related to competence of the maintainers

and both NCO and officer supervisors. The above are only indirectly related to cable age, although the older the cable plant, the more likely that a series of poor installers and managers have been assigned to the base. Once a plant is noisy, normal routine rarely quiets the plant and a conventional base overhaul does little to increase performance.

AFCS has attempted several times to form a program along the Scope Creek format where specially trained personnel provided with adequate test equipment would competently test, fault isolate, and correct basic problems. This program is called Scope Cap (Cable Assessment Program). The prime reason this program has been so slow and results so sparse is that the management pressure to correct the problems is low, even within the command because of lack of system grasp. For example, the standard set for cable noise is -40 dbmØ for a cable run of a few thousand feet, and many cables do not meet this standard. Yet -40 dbmØ is the performance to be expected of a well run backbone structure extending nearly around the world. The last few feet on a world wide phone call may be the limiting noise. The expression 'good to the last drop' is clearly applicable to the base cable plant. Each base structure -- for it includes more than the cable plant -- must meet standards of -50^{+} dbmØ if the long DCS circuits are to meet the no more than -37dbmØ standard -- user to user.

Also at present there is no one single person responsible for the proper operation of networks that reside completely within a base. The operation and maintenance of equipment and hardware is split among a number of agencies, none of whom views or is concerned with the satisfactory operation of the total base telecommunications function. Overseas, as

has been discussed under the Backbone section, and in the SYPAC Impact section, the base supervision can best be conducted by the Group supported by SYPAC/hardware elements.

The large conus HQ bases, the bunker command posts overseas, and the HQ locations of the major commands are different only in physical size and concentrations of communications. There is little in principle that makes these concentrations of people and communications different. However, in the conus, the DCS does not have large tech controls serving these locations since the backbone structure is leased. Also, most HQs and bunkers have a larger concentration of data processing equipment than is normally experienced. The performance assessment is straightforward, nevertheless.

The SYPAC concept requires the backbone structure encompass not only the microwave and tropo, but also the cable. The interconnection of terminals on a base or on a logistic support activity constitutes a major portion of the network. Performance assessment and control of the backbone interconnect structure and networks is identical in principle to that discussed previously in this SYPAC concept. The solution then is to view these bases as a small communication region that warrant a military tech control node. The tech control will be needed at the location of the main frame if the actual facilities are leased. The access needed for performance assessment can be met by bridged connections, so there is no technical impact on the carrier, and he has no legitimate reason to complain. The activity of this tech control is functionally the same as all overseas tech controls, except that there will be little if any microwave or

broadband effort. The terminal assessment and network and signal analysis activity will be enlarged, and there will be a measure of network control assigned for certain complex special nets. The amount of performance assessment hardware required will be determined by each special case, but in general will be less than a smaller node in the overseas DCS.

There is one factor discussed above that is common to all bases where the backbone structure is leased, the performance of the common carrier is unknown at present. Overseas, SYPAC will assess the circuits, groups, or other leased portions. For the bases in the states, the problem is both more constrained and also harder. The 2600 Hz tone can be used as before to assess the condition of the incoming autovon access lines. The autodin circuits can be checked from the switch and by other SYPAC techniques assess the network viability. All dedicated circuits can be evaluated end to end. For the reasons covered in Chapter II, the circuit by circuit analysis is not acceptable for fault isolation and area management, but it clearly can be suitable for legal action to recover costs for services not provided. High priority and low population density command and control nets can be assessed similarly to the DCS overseas, and performance margins can be measured. It will be slow and tedious to force the commercial carriers to provide acceptable channels full time since they are not interested in such premium performance even for themselves. This approach is described more fully in the chapter 'SYPAC in Conus'. The measurements also are basic to any communication structure analysis and planning for upgraded or expanded base or network facilities. Thus, the installation of a small tech control at all conus bases and camps is needed and is

probably cost effective because some duplicate circuits can be deleted with the expectation that the remaining ones can be made to perform more nearly as contracted. Overseas such tech control will not be necessary!

This approach is likely to be viewed with less than unbridled joy, by the concerned commercial carriers who have never heretofore been forced to provide guaranteed and assessed service. Nevertheless such an approach must be implemented if the communication leased costs for DOD are to be minimized, but with still an assurance of operational suitability. One point, however, is absolutely clear. Base telecommunications plants are always involved in any normal communication interconnection and are routinely one of the, if not the, prime limiters of system performance. As such, the base communication structure must assume a far more important role than in the past.

D. Integrated System Assessment

In all of the previous discussions, the backbone structure and the networks have been addressed separately. The approach was selected to ease the tutorial problems of explaining concepts, techniques, and approaches.

In the SYPAC actual field implementation there will be few measurements that relate only to the backbone structure or to the networks. It is technically more desirable, operationally more useful, and much more cost effective to accomplish system assessment. ATEC has provided hardware and operational validation of this new approach. Ref. Figure 5-1. Suppose that a conventional 1000 Hz tone were inserted at point A, and it traverses the DCS to point E, technicians in both the military and the commercial

worlds would know what to do.

In real life a signal -- a more complex signal -- is inserted at point A by the user terminal, and it traverses the DCS to point E. The parallelism is perfect. Why not use this real signal as though it were a test tone? This approach would then make it possible to perform the necessary channel assessment:

a. with no customer service denial while the test tone is inserted
b. with no personnel at the point A to connect the test tone
c. no test signal generator
d. and conducted at any point without pre-arranged scheduling of maintenance personnel all along the route of interest.

SYPAC will provide this ATEC proved capability. It is strange that few professional communicators really appreciate the immense capability of a computer/software based digital filters with software controlled characteristics, and the fast Fourier transform with the software capability to recognize the signal using stored signal characterization data. Of great importance, each time some new or better capability is devised, only the software need be changed. No hardware replacement, no overbuild and no discarding of resources need result. SYPAC/ATEC can sense the normal network signals and control tones, and process the measurement through using a fast Fourier transform and also examine the signal directly in a number of other ways -- using the same input sampled data for all analysis. The SYPAC use of digital filters and Fourier processing make the use of a 1000 Hz or any other special tone unnecessary.

1. Network/Broadband Assessment

The SYPAC performance assessment using the in-service non-disturbing examination of normal network signals as demonstrated by ATEC, however, gives a much broader base of information and is a considerable modification of the 1000 Hz test. The explanation of the capability to assess a whole system, using multiple analysis from network signals will be built sequentially for ease of understanding. The system assessments will be made at all major tech controls and focus at major nodes colocated with network switches. The readings are 'inservice' measurements normally requiring no activities from anyone elsewhere in the structure, although they may be software programmed simultaneously all through the system for certain of the measurements. The first basic example is quite simple and concerns making selected system measurements on parameters associated with the basic DOD network-Autovon. See Figure 5-29. Rectangles, designated by the letters A through K,represent Autovon switch locations in Europe. The lines represent the interswitch trunk configuration for the Hillingdon A switch. There are normally a number of voice channels represented by each line. Switch D is connected to switch A through C by interswitch trunks (IST) that traverse 13KF hops. Recall that the Autovon switches are colocated with the major node tech controls measurable audio to audio paths.

The manner in which the Autovon network IST's are measured by SYPAC, as demonstrated by ATEC, is illustrated below. See Figure 5-30. Tech Control A, where this measurement was taken,was connected to D by a direct circuit ATEC identified as 008. The 2600 cycle tone initiated at D was

AUTOVON TRUNKING MEASURABLE AT HILLINGDON

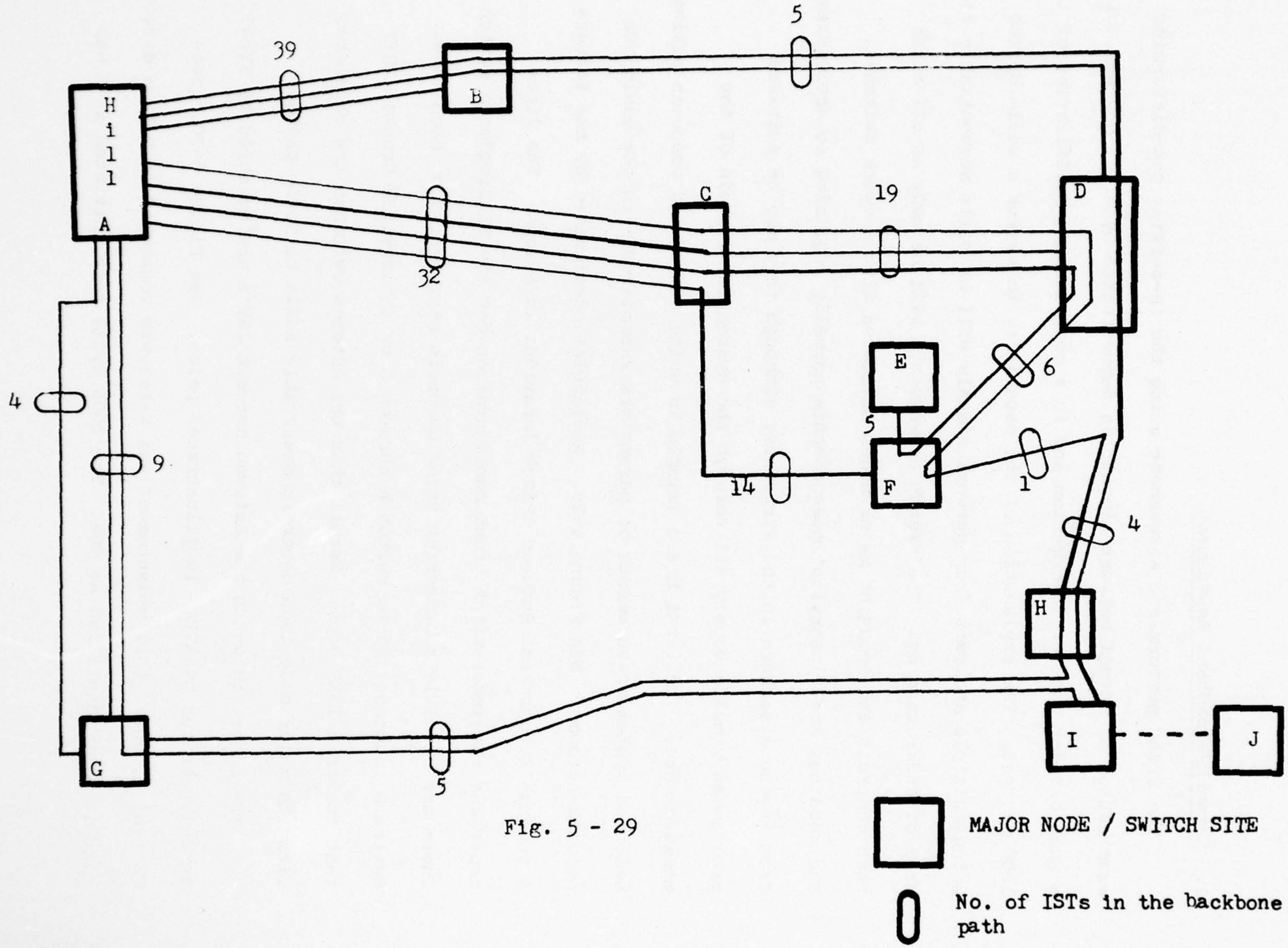


Fig. 5 - 29

ATEC AUTOVON 'In-service' Assessment

```
! MI,8,2,3

RH  WN-49.5 S  226/0849 008
AV-19.8G  FR+2601G  WN-49.5RH  SN+29.6RL  WF-48.6    NF+2000
 VU-19.7 PA+00.9 SW+0070 FR+2601 M5+00.3

SPECTRUM 6----5----4----3----2----1----0----1
 01 -62.9
 02 -65.1
 03 -66.3
 04 -67.0
 05 -67.8
 06 -67.4
 07 -65.4
 08 -64.8
 09 -61.7
 10 -64.1
 11 -62.4
 12 -58.4*
 13 -57.6**
 14 -60.1
 15 -59.0*
 16 -62.0
 17 -59.2*
 18 -63.7
 19 -61.4
 20 -54.3***
 21 -55.6***
 22 -62.0
 23 -60.0*
 24 -55.4***
 25 -25.9********************
 26 -19.8***********************
 27 -25.8********************
 28 -51.4*****
 29 -52.3****
 30 -61.0
 31 -62.8
 32 -61.9
 33 -63.3
 34 -63.3
```

Fig. 5 - 30

terminated at A on an SF unit so the channel was terminated at both ends and the in-service bridged measurement is valid. The switch tone level, AV is -19.8db, -- hot .2db, the frequency is 2601. - 1 Hz high. The 3KHz flat noise WF is -48.6dbmØ. The C message weighted noise WN is -49.5dbmØ. The path noise is high and the channel is obviously degraded. The spectrum plot clearly shows three tones present at 1300, 2100, and at 2900 cycles, in addition to the desired 2600 SF tone. If the source of the tones were located and corrected, the path then would perform at about -57 dbmØ -- more than 8 db quieter.

Figure 5-31 illustrates the performance of channel 008 at 0845, four minutes earlier, but with the 2600 cycle tone blocked and the channel terminated. Nothing else was done to the circuit. The 3KC flat noise WF is -48.3. The C message weighted noise -48.8 dbmØ. These readings are in agreement with those of Figure 5-30, and the ±1 db variations are normal for any circuit when readings are taken a few moments apart. Note that the tones were present, but that the frequencies are slightly different and appear at 1400, 2200, 3000. After these two tests, an amplifier was used to listen to the channel. These slowly drifting tones were clearly audible. ATEC had provided the data in very explicit and easily usable form.

One measurement of one IST does not define the link performance, however, there is more than one IST between the two locations D and A. After the above system measurement is conducted on each not-in-use trunk, the composite link performance can be automatically derived. An ATEC demonstration of this approach was conducted. See Figure 5-32. In

ATEC AUTOVON 'Out-of-service' Assessment

MI,8,2,3

AV-46.5 I 226/0845 008

AV-46.5 NF+3000 WN-48.8 FN-46.8 WF-48.3 NC+12.4
P1+00.9 X5-46.0
VU-46.1 PA+08.8 SW+1218 FR+2980 M5+01.2

```
SPECTRUM 6----5----4----3----2----1----0----1
 01 -62.3
 02 -67.2
 03 -64.9
 04 -64.0
 05 -65.2
 06 -66.3
 07 -67.0
 08 -66.7
 09 -65.3
 10 -65.3
 11 -66.7
 12 -65.9
 13 -61.1
 14 -58.6*
 15 -60.4
 16 -64.0
 17 -65.4
 18 -65.8
 19 -63.5
 20 -63.7
 21 -57.9**
 22 -54.5***
 23 -59.7*
 24 -60.5
 25 -59.9*
 26 -60.1
 27 -63.4
 28 -64.5
 29 -54.0****
 30 -51.1*****
 31 -57.2**
 32 -61.7
 33 -65.6
 34 -66.9
```

Fig. 5 - 31

SCAN of AUTOVON INTERSWITCH TRUNKS

Channel No.

```
G   WN-64.5 I  050/0231 007
AV-58.4     NF+0100    WN-64.5G    FN-59.8     WF-60.3G    NC+10.9

      AV-20.8 S  050/0231 008
AV-20.8     FR+2600    WN-59.2     SN+38.3     WF-56.7     NF+0100

      AV-20.7 S  050/0231 012
AV-20.7     FR+2600    WN-58.2     SN+37.5     WF-56.1     NF+0100

      AV-22.0 S  050/0231 022
AV-22.0     FR+2600    WN-58.9     SN+36.9     WF-55.9     NF+0100

      AV-21.1 S  050/0231 028
AV-21.1     FR+2600    WN-57.1     SN+36.0     WF-55.4     NF+0000

RH  WN-51.5 I  050/0231 030
AV-47.4     NF+1800    WN-51.5RH   FN-49.5     WF-50.5RH   NC+07.6

      AV-28.1 S  050/0231 035
AV-28.1     FR+2600    WN-64.5     SN+36.4     WF-59.7     NF+0100

      AV-26.0 S  050/0231 036
AV-26.0     FR+2600    WN-62.5     SN+36.5     WF-58.3     NF+0100

      AV-21.9 S  050/0232 038
AV-21.9     FR+2600    WN-58.6     SN+36.7     WF-56.5     NF+0100

      AV-05.5 TT 050/0232 050
AV-05.5     FR+0995    WN-56.0     SN+50.4     WF-52.1     HD+54.1

      AV-21.1 S  050/0232 059
AV-21.1     FR+2600    WN-59.2     SN+38.1     WF-57.0     NF+0100

      AV-23.1 S  050/0232 060
AV-23.1     FR+2600    WN-60.9     SN+37.8     WF-58.2     NF+0100

AH  WN-56.1 I  050/0232 061
AV-54.2     NF+2600    WN-56.1AH   FN-54.1     WF-55.3G    NC+17.3

      AV-11.9 TT 050/0232 069
AV-11.9     FR+0995    WN-61.4     SN+49.5     WF-58.8     HD+53.0

      AV-24.3 NL 050/0232 072
AV-24.3     PA+04.1    PI-20.2     FL-22.0

END OF
TEMPORARY SCAN 4
```

Fig. 5 - 32

practice the printout would not be necessary with the computer performing appropriate manipulations and printing out the link performance parameter or other programmed answers of interest. In this specific test, of course, the data reduction was manual, since the reduction algorithm was not yet implemented. The test was set up to scan 15 interswitch trunks from Feldberg to Hillingdon, spanning 2 weekdays. Several important conclusions were made in near real time, even with manual analysis. The trunks were scanned several times to be sure that no anomalous conditions were inadvertently missed, to be sure that the circuits were really in use, and to differentiate between test tones, voice and data traffic.

The Figure 5-32 printout/scan printed started at 0231 Z and completed at 0232 Z. The 3KC flat noise measured on these channels is as follows: Channel 008 is 56.7, 012 is 56.1, 022 is 55.9, etc., and 061 is 55.3 dbmØ. The link performance average will easily be calculated by SYPAC software to be -56.7 dbmØ for the 10 idle trunks. Only fair performance. There were several problems introducing noise later isolated to a poor baseband bridge and several noisy baseband cables. Note also that 8 of the 10 trunks had 100 Hz power line hum as the predominate noise. The performance should have been about -62 dbmØ.

Thus the backbone structure is assessed, but as a by-product of the Autovon network assessment. Also the following network information, much of which is not available from the switch traffic data collection system. (TDCA) was derived.

The scan shows that 10 of the 15 trunks were idle -- 2600 Hz tone

present. The TDCS would have shown the same figure. TDCS would have shown that 5 trunks were in use. ATEC, however, showed a different picture.

ATEC showed that channel 050 spent all but the first few minutes in full time data service. Another channel, 007 was presumably in service but for none of the 120 scans was any modulation present.

The switch is supposed to be statistical in the selection of interswitch circuits within the voice grade and then similarly non-biased in the selection among data grade trunks. It clearly was not. A fault was surfaced when it was noted that the switch assigned data grade circuits first with the overflow traffic placed on voice grade trunks. The switch software trunk selection program had been reversed. 2600 cycle tone absence did not equate to a circuit in use, nor is this case exceptional. It has been demonstrated a number of times by both the commercial carriers and the military that careless installation or inadvertent grounding of the 'E lead' has fooled normal traffic counters into thinking that these trunks were busy full time. SYPAC software can keep an accurate record and be sure that at the end of each shift or other suitable time period, the 2600 cycle tone has appeared, to demonstrate that the trunk itself is not defective and that some modulation appears periodically when the tone is absent to prove that the channel is in use.

There is also other data of interest. The 2600 cycle tone is supposed to be at a -20 dbmØ level to properly signal the switch. The level was undetermined on one channel because of the full period data usage, and on 007 because it was never usable. 7 signalling levels were normal, 3 were -1 db outside standard limits, 1 was -4 db, 1 was -6 db, and 1 channel

(035) was -8 db low. All level errors were on the low side. Three circuits were unable to process a 'normal' call, that is they never showed a call lasting past one scan. The calls thus were always less than 1 minute. They really were not established at all. Clearly these three circuits or hardware in them are suspect. Certainly calls can be that short, but the properly performing circuits had few of these one scan calls. It was this peculiar scan behavior that caused the author to initiate a SF unit special study covered earlier under Autovon, that found 15% of all SF units defective in one or more aspects. Although the calls were never established, the Traffic Data Collection System peg counter would log these faulty attempts as calls.

There are many other capabilities of note, deriving from these scans. For example, channel 007 was presumably in use, but at this scan moment, no traffic was present. This can be surmised by comparing the idle channel voice measurement with others in the same trunk. 007 = -60.3 dbmØ vs. others running -58 to -64 dbmØ when out of service. No traffic was ever present, and this can be proved when compared to itself at each scan time -- no 2600 Hz tone, no modulation and the predominant frequency present is shown to be power line hum -NF-100 Hz.

Channel 030 is also idle. Although the 2600 Hz tone is absent, the predominant frequency is 1800 Hz, but at such a low level, -47.4 dbmØ that it must be a cross talk tone of chance or discrete cross talk from the weather fax net. In either case, the idle channel noise is 10 to 12 db above that expected and would be cause to initiate fault isolation.

Both 1000 Hz nominal test tones are measured by ATEC to be 995 Hz. It is likely that both test tones are from one malcalibrated test oscillator source. The frequency offset of the path is not suspect since the 2600 tones are all correct.

It was further ascertained that the full period data service user was not following prescribed procedure. All data services are supposed to be removed periodically and then re-established. Only SYPAC (ATEC) type scans are likely to detect this type of circuit misuse.

The 2600 signal level and channel noise was only mildly related to switch preference for certain circuits, and did not account for most of the switch bias. The voice levels were a bit high on most channels, judged by ATEC PI measured voice peaks above 0 dbmØ.

Clearly much corrective action is required, but until this scan test no one knew of any problems, and everything was 5 by!

There is a logical extension of this technique that is very useful in validating link performance figures. This technique, however, has other uses that will be explained later. There are long interswitch trunks that go not to the adjacent switch, but to switches several major nodes removed. The measurements by SYPAC are identical to those demonstrated by ATEC in the Figures 5-30 and 5-31. These measurements also are made on an 'in service' basis. Reference Figure 5-29. Using this technique, ATEC has assessed the major node to major node paths

G to A	D to A	
I to A	D to B	F to A
I to G	C to A	F to C
B to A	D to C	etc.

including every path from every Autovon major node/switch sites except J.

A special extension connection J to I was made and added to the I to A path. The J to A and J to I paths were evaluated.

Bear in mind that Donnersberg, Germany, (Major Node E) is connected to every switch in Europe. Donnersberg ISTs are in addition to all of those shown on Fig. 5-29. When all of the other switch ISTs are added, it should be self-evident that the PMP backbone assessment is well measured as a by-product of the Autovon network assessment. There are a number of ways to correlate the data. All the long elements of the backbone structure can be validated. The longer paths are excellent for quick area assessments. A link assessment from I to A is quite reasonable technically.

The reason for measurement of these long paths is more basic than just substantiative information. There have been a number of cases where noise has been present in a tech control or at a site. When measurements were made from the troubled tech controls to either side, the readings were normal, but when the measurements were made from the two adjacent locations through the troubled site, the noise was evident. The explanation was simple. The noise entered the circuits via a ground loop and so was present on the trough paths. Local measurement broke the loop and the noise was not present.

Thus using the major node/switch to major node/switch assessment, buttressed by long-path verification a complete and valid status is achieved.

The entire mainline Autovon trunk routes -- and concomitantly the entire European broadband framework -- can be checked in a few minutes by SYPAC using the above concept.

Quite clearly, of all the main line Autovon ISTs are acceptable there is no need for major management attention. If a section is ascertained as degraded, the direct measurements and the correlative multinode IST assessments assure fault isolation to the concerned major node to major node link and give sufficient information normally to identify whether the difficulty is a group, supergroup, master group, or total link problem. (By comparing the various IST trunks over the same RF path.) If the problem is a major one, the Area and HQ will be interested. The long interswitch trunk approach will let the Area and HQ follow the backbone status without numerous and voluminous reports from the sites. If Region corrective response is not acceptable, the Area can redirect resources to solve the problem faster. If the problem was expeditously corrected, accolades would be in order.

If the problems are less severe, but still below a mid-Amber threshold, the Area can periodically spot check and monitor the Region/Group reaction and rate of progress. Of course, small problems should be ignored by Area and HQ except as monthly or quarterly summary data and as comparison data.

2. Network/Tail Link Assessment

The Autovon network also has trunks from the major node/switch location to a number of bases. The base exchange has SF units and to all appearances, the 2600 Hz tones, signaling, traffic and user signals, are technically similar to an IST. The above described ATEC procedure will be used by SYPAC to assess these base exchange to switch trunks, both to derive the

AD-A047 896 GEORGIA INST OF TECH ATLANTA SCHOOL OF ELECTRICAL ENGINEERING F/G 17/2.1
SYSTEM PERFORMANCE ASSESSMENT AND CONTROL CONCEPT (SYPAC)
OCT 77 FEIK, ROBERT CONTRACT NO. F30602-75-C-118
UNCLASSIFIED 428P PROJ. 9567 N/L

4 OF 5
AD A047896

traffic and usage information and also to derive the tail link path performance numbers. The tail path can be assessed from the major node switch only in the base to node direction without cooperative help. However, the automatic base exchanges have a built in remotely controllable exchange loopback feature; and manual exchanges can be quickly looped by the operator. The loopback need only be held for 3 to 4 seconds, so little operational impact need be experienced. The procedure is as follows: base to switch performance is assessed, by SYPAC as previously described. Then the switch to base to switch loopback is evaluated. By simple math, the loopback number minus the base to switch reading gives the switch to base performance figure.

The broadband framework, tech control to tech control, ascertained from the switch IST assessments now can be expanded to include the connective structure base to base. This is considerably more data than is available presently, but still does not include the last drop -- the cable structure to the final users.

3. Network/Cable Plant Assessment

There are several reasonable approaches to assess the base cable plant. The easiest to implement is to take one cable pair in each major cable run on base, terminate it, and assign it a special phone number. Thus the switch can 'call' these numbers and measure appropriate parameters, including noise. Since a cable is reciprocal, one measurement is adequate. Thus the cable to switch measurement minus the base exchange to switch measurement is the cable alone assessment. Normally, only a dozen or so

prime base cable assessments are required. Obviously a special long base cable pair threaded through the key cables would assess all cables in one reading.

There is another approach that does not require any special action and is a direct by-product of network assessment, and this is the best way. The lower speed data terminals used by Autodin or other data nets do not occupy the entire voice channel, and leave much of the bandwidth undisturbed. Thus any noise or signal that appears in this unused portion of the channel is measurable in-service and non-customer disturbing.

Figure 5-33 shows an ATEC printout of a 600 band modem at the transmit end. This signature is recognizable and can be used to validate the circuit usage data base records at any transited tech control. The frequency spectrum up to about 1500 Hz is unused and the spectrum above 3300 is also unoccupied. Figure 5-34 shows this terminal signature after it has travelled over a fairly long path in the DCS. The noise added by the path is clearly evident and fairly high, and calculates to an idle channel noise of the equivalent full channel of approximately -50 dbmØ. The spectrum from 3000 to 3400 shows some distortion products. In this case, the received signature and noise assessment was made a long way from the generating base. The first serving tech control would also have made an automated ATEC type assessment. The noise measured there would have been indicative of the user/cable status. An analysis of the two measurements can quickly determine the noise and distortion attributable to the backbone structure, and this requires lateral orderwires.

```
AH    PA+Ø3.3 NL 25Ø/1841 13Ø
AV-13.5G    PA+Ø3.3AH    PI-1Ø.3G    R4+Ø3.3
AF+Ø6.1     P5+ØØ.5      X5-13.Ø     NC+ØØ.Ø    NF+ØØØØ    NW+Ø456
SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -64.Ø
 Ø2 -67.4
 Ø3 -71.6
 Ø4 -73.8
 Ø5 -75.1                     103E
 Ø6 -76.6                      Tx
 Ø7 -77.5
 Ø8 -74.2
 Ø9 -72.7
 1Ø -73.9
 11 -76.Ø                                600 BAUD MODEM
 12 -72.3                                TRANSMIT
 13 -71.3
 14 -7Ø.8
 15 -69.7
 16 -64.3
 17 -52.3****
 18 -41.2**********
 19 -3Ø.1***************
 2Ø -2Ø.Ø********************
 21 -18.5*********************
 22 -22.7*******************
 23 -22.2*******************
 24 -21.3********************
 25 -22.6*******************
 26 -23.1*******************
 27 -21.1********************
 28 -26.4*****************
 29 -34.5*************
 3Ø -42.3*********
 31 -51.Ø*****
 32 -62.Ø
 33 -7Ø.1
 34 -73.7
 35 -77.9
 36 -77.Ø
 37 -76.8
 38 -72.8
 39 -69.6
 4Ø -65.3
```

Fig. 5-33

```
G*F  AV-12.9  NL 25Ø/1651 Ø22
AV-12.9G*F  PA+Ø4.1G    PI-Ø8.7G    R4+Ø3.6
AF+Ø5.3     P5+ØØ.8     X5-12.1     NC+ØØ.Ø    NF+ØØØØ    NW+Ø525
SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -55.2***
 Ø2 -57.Ø**
 Ø3 -54.Ø****
 Ø4 -51.7*****
 Ø5 -52.0****                                 103E
 Ø6 -52.4****                                  Rx
 Ø7 -52.2****          Channel
 Ø8 -51.3*****         Noise
 Ø9 -51.6*****
 1Ø -5Ø.8*****
 11 -5Ø.4*****
 12 -5Ø.8*****
 13 -49.7******                                           600 BAUD MODEM
 14 -5Ø.9*****                                            RECEIVE
 15 -51.6*****
 16 -5Ø.8*****
 17 -47.4*******
 18 -39.3***********
 19 -3Ø.9***************
 2Ø -21.8********************
 21 -19.5*********************
 22 -21.8********************
 23 -2Ø.3********************
 24 -2Ø.5********************
 25 -22.1*******************
 26 -21.7********************
 27 -18.4*********************
 28 -23.9*******************
 29 -33.7**************
 3Ø -41.3**********
 31 -46.4*******
 32 -48.5******
 33 -5Ø.4*****          Distortion
 34 -53.5****           Products
 35 -56.5**
 36 -63.1
 37 -78.8
 38 -84.8
 39 -84.1
 4Ø -8Ø.9
```

Fig. 5-34

There are normally 5 to 15 of these lower speed terminals on base, so it is reasonable to assess the whole cable plant with no special cable plant tests required at all -- they come as a parallel output of the Autodin or other network/system assessment. A prime output also is to check terminal signature parameters at the serving tech control to be sure that no terminal induced problems exist.

Figure 5-35 and Figure 5-36 are two of the other modems that also provide similar network terminal, signal degradation, and cable plant assessment. It is obvious that a software digital filter/fast Fourier transform is the only viable approach to this system assessment issue. A hardware assessment approach could not be either effective or flexible with the 30 to 50 signatures now present in the DCS with additions and deletions as user needs demand.

The cable plant assessments, added to the tail path evaluations plus the broadband IST measurements are now truly representative of the backbone structure -- the user to user connective circuitry. Of maximum interest also is that the entire structure has been assessed customer non-disturbing from central points in the DCS -- the major node switch site -- all unsupported by any additional personnel at the base or at the user locations.

In a few cases, such as high level alerting nets for commanders and command and control networks, where the terminal or phone may not be used often, it may be desirable to place a beeper or loopback on line to provide a full time proof of connectivity, and SYPAC can use it along with the circuit assessment to prove both connectivity and acceptability.

```
231/1528 OPERATOR SIGN ON:
MI, 184,1
AV-12.5  WH 231/1529 1Ø4
AV-12.5   PA+Ø4.8   R2+Ø3.3
VU-12.5   PA+Ø4.8   M5+ØØ.5   FR+1522   SW+1155
VU-12.5   PA+Ø4.8   SW+1155   FR+1522   M5+ØØ.5
SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -58.Ø**
 Ø2 -58.7*
 Ø3 -66.1
 Ø4 -71.3
 Ø5 -73.4
 Ø6 -74.4
 Ø7 -73.9
 Ø8 -72.8
 Ø9 -7Ø.7
 1Ø -66.1
 11 -59.7*
 12 -5Ø.4*****
 13 -32.Ø**************
 14 -19.6*********************
 15 -16.4**********************
 16 -17.8**********************
 17 -24.3******************
 18 -42.Ø*********
 19 -58.9*
 2Ø -64.5
 21 -67.Ø
 22 -65.Ø
 23 -52.5****
 24 -37.6************
 25 -25.2******************
 26 -22.2*******************
 27 -22.1*******************
 28 -21.2********************
 29 -2Ø.7********************
 3Ø -28.2****************
 31 -43.8*********
 32 -58.6*
 33 -67.4
 34 -71.6

231/1529 O/I END
```

AUTODIN 150 + 300 BAUD
MODEM TRANSMIT

Fig. 5-35

231/1517 OPERATOR SIGN ON:

1 MI,ØØ6,1,3

G AV-12.6 WM 231/1517 ØØ6

AV-12.6G PA+Ø6.3G PI-Ø6.3G R1+Ø6.4

VU-12.4 PA+Ø6.3 M1+Ø2.2 M5+ØØ.4 FR+Ø877

VU-12.4 PA+Ø6.3 SW+Ø954 FR+Ø877 M5+ØØ.4

```
SPECTRUM 6----5----4----3----2----1----0----1
 Ø1 -56.3**
 Ø2 -58.3*
 Ø3 -61.6
 Ø4 -61.7
 Ø5 -61.5
 Ø6 -59.4*
 Ø7 -53.2****
 Ø8 -23.2********************
 Ø9 -17.9***********************
 1Ø -20.4*********************
 11 -18.4**********************
 12 -19.4**********************
 13 -21.0*********************
 14 -27.6******************
 15 -50.1*****
 16 -59.9*
 17 -67.5
 18 -67.9
 19 -68.Ø
 2Ø -66.3
 21 -6Ø.8
 22 -51.2*****
 23 -28.3*****************
 24 -19.2**********************
 25 -22.4********************
 26 -44.2********
 27 -58.Ø*
 28 -64.2
 29 -66.1
 3Ø -67.7
 31 -7Ø.3
 32 -69.5
 33 -69.4
 34 -72.2
```

231/1518 O/I END

AUTODIN 300 + 150 BAUD
MODEM RECEIVE

Fig. 5-36

The above information gathered on the backbone, the tail links, the cable plants can be recorded and compared against performance standards and can be gathered in real time: to determine "Is there a problem" in the user to user connective structure.

All performance parameters of interest can be trended and correlated as desired to answer "Is there an adverse trend?".

The above overview gives the needed information to derive "How are subordinates doing?" on hardware maintenance.

All of the above is gathered with no (or trivial) activity by the subordinate echelons. Good commanders and managers are clearly identified, and the system status is always known.

4. Network/Network Assessment

The three previous sections discussed the SYPAC concept, as demonstrated by ATEC, for assessing all of the elements of the interconnect structure. All of this performance assessment is derived as a by-product of network measurements. This section explains the concept for using the network/system measurements for network performance assessment.

An examination was made of each of the 128 scans of which Figure 5-32 is one to determine circuit availability for a call. Leaving out the defective circuit and the full time data circuit, thirteen channels were available. At night at least 10 circuits were always available normally 11 or 12. In the daytime scans, the average was 6.9 circuits available on the Hillingdon ISTs alone. Of the 67 daytime scans, one scan had one

free trunk, one scan had two, two had three, and six had four free circuits. All of the other 58 scans had five or more circuits. Obviously, there are no trunk fill problems. If the defective circuits were fixed, there would even be less reason to worry about lack of suitable circuits both for call usage, and also for the system scan assessment and analysis. On the C to A RF path there are also three other sets of ISTs, so that a PMP type link characterization is always possible. This type scan derived data clearly provides system information from a system wide view point. The Region/Group can use it to validate the link data reported from lower levels, and Area managers can use it as the data from which the total broadband framework status can be derived. The VON network managers at Area can sense traffic flow and status -- in about a minute routinely or on call, with no disturbance to the mission.

The input and exit traffic summary date of key HQ base telephone exchanges can be assessed, and forwarded to a central point since this is where most command and control activities focus. SYPAC centralizes the assessment information geographically adjacent to the switch provided readouts and alarms. It is operationally advantageous to do this. There is no technical reason, however, and SYPAC can assess all of the same information at any midpoint along the trunks as long as a SYPAC (ATEC baseband signal analyzer) instrument is used or the ISTs drop to audio. The intercontinental trunk assessments both undersea cable and satellites have not been specifically described but were measured by ATEC. Since the principles are the same, such assessment can be accomplished by the

overseas and conus gateway stations whether the trunks terminate on the gateway switch or traverses the tech control enroute to switch.

In the case of Autodin, the assessments of the data traffic is not that of quantity of traffic since all circuits are secured and so chortle full time. Data statistics must be acquired at the switch, but since the switch and the tech control are collocated this poses no great problem -- if the information is programmed to be made available to the outside world by the switch.

There are of course many other networks, including Autosevocom. In general, this secure network is assessed much as Autovon plus PBX complex, since the Autovon network supports most of the secure interconnections. The ultimate most satisfactory approach to full assessment of Autosevocom will rest in a combination of Autovon network assessment overlayed by special secure voice network measurements conducted from the Sevocom switches.

During one period, assessments were made on Autodin from a midpoint location. Figure 5-37 shows the operational interconnection. Two remote Autodin switches are connected to a DIN switch down the hill one short microwave link from the ATEC instrumented tech control in Germany. Both the send and receive signals from all three switches were available for automatic scan. Both remote switches are about 500 miles distance. The top switch is routed entirely over a microwave backbone structure, the bottom switch traverses mostly tropospheric scatter. There is no reason to expect very much difference in the distortion to the signal due to the length of the path. Some people 'guess' that tropo introduces more distortion. The ATEC has clearly provided a determination, as portrayed in

the expanded insert. The peak to average ratio is the parameter for assessment on this particular DIN IST modem. The PA received from the remote switches was 4.0 and 3.7 db, with the better figure over the tropo path. The data of most interest, however, related to send signals from the local switch, traversing the one microwave link. Both signals have traversed identical hardware boxes and propagation effects, yet the send signal for the bottom switch is much more distorted than the other, 4.7 vs. 2.5 db. peak to average. One local signal was more distorted than the signals arriving from the switches 500 miles away. Obviously the answer to the question "Is there a problem" must be YES. The fault isolation is already obvious -- down to the troublesome link. A SYPAC baseband signal assessment could quickly identify whether it is arriving from the down the hill site or whether it is being distorted at the major node.

In any event, a problem has been detected and isolated with no coordination or cooperation required at any other location. Now it is well within the capability of local maintenance personnel to resolve and correct this problem. The difficulty, however, was not recognized until the author conducted this network/system scan. There was adequate time to complete the fault correction since the trend appeared to be very slow and the performance margin at the receive bottom switch should still be about 2 db assuming that the receive equalizer is properly adjusted. The 1800 Hz reset tone mentioned earlier did not appear, so this assumption is reasonable. When SYPAC assessment hardware is available widely, this last surmise could be validated at the lower switch and proper resources

applied to correct the problem before the hardware degradation produced customer difficulties. The problem also could have been detected at the remote serving tech control for the bottom DIN switch.

The most difficult problem facing the DCS is quite patently determining "Is there a problem." Normally, work progresses quite reasonably once the concerned personnel recognize and accept that there truly is a problem, and if they have a routine and effective approach to focalizing the difficutly -- SYPAC fills both these needs.

The discussion of network/base cable assessment showed how a number of Autodin network terminals could be used to measure the on-base cable conditions. The terminal signature are used like a test tone to assess signal level, distortion, and other relevant degradation parameters such as frequency offset. These parameters are assessed by a SYPAC software algorithms against preset thresholds and also compared with similar signals in a manner just described for Autodin in Figure 5-37.

By such measurements in each major node tech control, the slow build up of signal distortion with progress through the DCS can be observed. An increase beyond a threshold can be picked up easily and by simple domino testing in major nodes back toward the signal source can quickly find the disturbing segment. The straddling major nodes can rather easily sub-isolate to the offending link or site and then turn it over for local repair. The class of distortion, the pervasiveness of the problems, etc., all give generous hints in service as to the most likely location of the fault. Clearly instrumenting all major nodes is the prime step in SYPAC system Management.

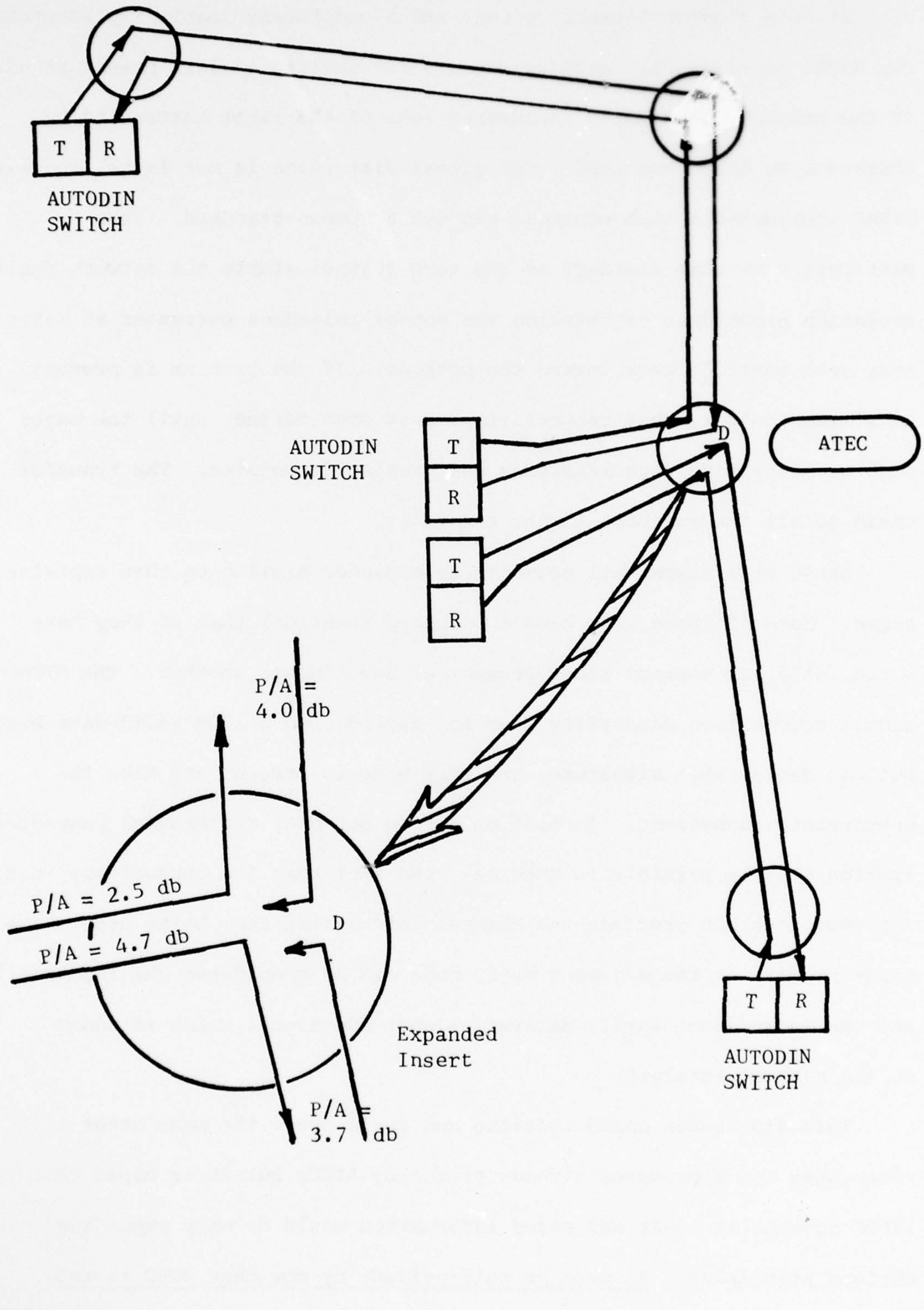

T
R
AUTODIN
SWITCH
AUTODIN
SWITCH
T
R
T
R
D
ATEC
P/A =
4.0 db
P/A = 2.5 db
P/A = 4.7 db
D
Expanded
Insert
P/A =
3.7 db
T
R
AUTODIN
SWITCH

Fig. 5-37

It is a straightforward concept and a completely viable implementation for SYPAC to assess all network signals for quality against preset standards. If the network is properly engineered (one of the first matters to be addressed by SYPAC and ATEC) the signal distortion is not large, and all SYPAC instrumented tech controls can use a common standard. Thus penetration of this standard at any tech control starts the network fault isolation procedures -- checking the out-of-tolerance parameter at major node tech controls back toward the problem. If the problem is present at a tech control, that control ripples it even further until the major node to major node path inserting the problem is located. The transfer could go all the way back to the terminal.

SYPAC will assess all networks in a manner similar to that explained above. Some of these nets have a combined function, that is they have voice, data, or control tones present at one time or another. The SYPAC signal recognition capability does not depend upon a 100% valid data base, but can decide what signature, and what mode is present and make the appropriate assessment. In most multi-use schemes, the channel characterization also is possible in service. The fact that the channel may initiate far away does not preclude the channel information from being used. The noise present at the adjacent major node can be considered the input noise, and the measurement easily determines what additional noise is added on the path of interest.

This discussion could continue and could cover the many other techniques and approaches already proved by ATEC, but it is hoped that the SYPAC concept is clear and added information would be only expanding obvious principles. <u>It must be self-evident by now that ATEC is not</u>

presently, and never was, an automation only of tech control measurements and the transmission media. SYPAC can be so portrayed even less.

Obviously, all networks including the special sensor and intelligence nets, etc., will be assessed using techniques already demonstrated, to examine the special and important parameters, after the appropriate parameters have been designated.

The present continued measurement and reporting of all possibly relevant numbers, as seems to be the governmental policy, could be continued at less expense by SYPAC, but that is no excuse for such waste of time, effort, and computer time and storage. In the SYPAC era, no data will be processed above the local or Group/Region level unless there is a logic and analysis concept and algorithms for producing informative and necessary data for some specific purpose at some particular organizational level. This requirement will produce better managers also.

The goals of the system scans have been stated earlier in this report. But an orthogonal view may help clarify the real needs. Overseas, where the DCS is most heavily disposed, HQ's are being cut, far beyond the capability to do the management job as previously conceived. It is clear that the Area HQ will not be rebuilt, nor can the communication structure be permitted to continue to decay. Therefore, the HQ must dramatically change its functions -- and direct technical supervision cannot be one of the surviving activities. HQ overseas must shift to broad technical overview, to long-range planning and programming, based upon a total integrated grasp of the communication needs of the entire Area. This understanding must be based upon an overview form of system requirements

engineering. This is not the system engineering assigned to DCA, it does not concern the establishment of VOCODER data rates, or whether to go to TDM and abandon FDM. These technical issues are quite apart from the matters that face AF, Army, Navy, and Joint HQs in Europe or in the Pacific. The Area HQ issues relate to what are the functions that the Air Forces in theater must accomplish, where are the major command and control centers, how much diverse routing of circuitry is required to avoid battle areas during the conduct of hostilities, what special data requirements exist, and what is the impact of large HQ movements or relocations, etc. None of these functions can be solely handled by DCA, and in most cases must be addressed primarily by the service concerned. This broad examination historically has been much too late in the time cycle and has been based upon abrupt and incomplete planning -- or in some recent cases -- after actual implementation of the action with gross mistakes corrected at a later date.

The three services have until recently each considered their operational needs more or less independently of the other services and DCA. Fiscal considerations as well as technical disruptions and system logic mediates against continuation of this approach. Area HQ in the future will do the supportive and requirement planning for the Departments and for the Unified and Specified Commands and will assure that the separate service needs are programmed and implemented, and will work closely with the DCA engineering agency to assure that the resulting structure meets the real operation requirements on the needed time schedule,

with quality communications.

SYPAC system assessment, in this light, becomes one of the key , and probably the best, source of information related to the communication service provided by the plant in place system.

The planning in a stable environment will entail minor changes in configuration to optimize the communications performance, or lower the overhead cost while still retaining acceptable performance. This last cost savings related to performance has never been possible before, but will be viable under SYPAC. Recent O&M and HQ reductions have been nearly arbitrary and based upon data so fragmentary and filled full of errors that the resultant cuts have been highly degrading to system operation. In a controlled changing environment, such as now facing the U.S. overseas, the planning can be based upon known performance records and statistics. During hostilities, of course, the planning and reactive actions will be much less well ordered, but nevertheless, can be based upon measured and up to date performance, provided by SYPAC/ATEC.

VI. SYPAC IMPACT (BASIS FOR COST SAVINGS)

As effective system performance assessment and control (SYPAC) is provided to the DCS, it will provide the means to dramatically improve the operational effectiveness and cut O&M costs of military communications. It must also lead to the significant alteration of the supporting and overhead structure to achieve this greater efficiency and improved cost effectiveness. Also, it will force a dramatic reexamination of all facets of the planning, development, procurement, operation, maintenance and management of the total communication entity. The words 'offer the opportunity', 'provide the means', and 're-examination' are used advisedly, for it is always possible to have an opportunity and miss it entirely, or fail to take full advantage of all circumstances. There are always, of course, those who resist change and those who have high internal inertia and prefer whatever requires the least work. Nevertheless, SYPAC is a concept whose time has come and it must be understood in depth, programmed fully and implemented effectively. The time to develop the necessary in depth understanding throughout the communication structure and the ever present large mental inertia, mediate against an overnight SYPAC introduction even if this were fiscally possible. The hardware implementation will have to be incrementally time phased with organization, personnel, training, and the most difficult element -- management changes. The first steps to most effectively achieve maximum communication gain for least cost is stated in the last chapter.

All authors who address automation invariably promise that the

phenomena to be automated can be done faster, better, and cheaper. All manufacturers who produce automation equipment echo such happy predictions and push centralized vs. decentralized control or micro vs. mini processors in self-serving interest. However, the people who automate may or may not accrue the promised gains. The failure of automation to deliver 'utopia' is not necessarily the fault of any one group. It is not, however, the responsibility of authors, or of the many producers to see that the operational need is met. The need for automation can only be expressed by the user and operator and only he can be sure that all of the delivered elements are properly matched to meet his need. It is futile to assume that the developer understands the operational need. It is even more pointless to hope that he will learn during the development and test cycle since his goals are always different and often opposed to those of the user. A hardware buy and a programmed installation is not routinely followed by quick and easy gains and savings of all sorts. The SYPAC author, like all others, promises faster, better, and cheaper, and in dramatically very large measures, and operational gains apparent to all users but not just by hardware procurement. The SYPAC gains are achievable only if all echelons of the communication organization take all the concomitant steps required to achieve an integrated approach to the total effort including organizational hardware, software, orderwires, and personnel -- total management.

If these mandatory parallel steps are not taken, the cost effective returns will be less. It is conceivable that in some combinations of awkward accomplishment the effectiveness could be negative. If the

sequence of accomplishment is not as outlined in the last chapter, the gains must be low or negative.

A. Operational Impact

The conceptual changes to be discussed quite obviously will have a major effect upon all operational levels. Just how dramatic these changes will be is discussed below.

In these times of severe defense department retrenchment, the cutbacks were so deep that on many occasions needed functions were killed, and capabilities that are required in war time were destroyed. These reductions have been leveled upon the various segments within the DOD based upon broad re-examination of the reduced military goals forced by the cutbacks. There is continuing rebalancing of fund allocations to recover money for new projects, and to cover cost increases. Thus funds for SYPAC will receive close examination.

The SYPAC approach was originally posed in the SATEC report as being cost effective based upon greatly improved communication capability and with large cost avoidance savings. This gain was to be achieved by reacquiring the inherent performance achievable by the plant in place. TEP validated that 15 to 20 db of worldwide plant degradation had occurred. The PMP was formulated as a partial manual equivalent to SYPAC both to prove the concept and also to recover some portion of the deterioration to the system. Both goals were met. The SYPAC concept clearly is viable and a 7 to 10 db improvement worldwide in the backbone structure was documented before the Air Force management structure was decimated. This, however,

still left 5 to 15 db yet to recover at a minimum, and the amount is greater presently.

Nevertheless, funds for SYPAC are still questioned recurringly. Technically astute personnel can readily convert performance recovery to 'effectiveness' and so derive a favorable cost effectiveness figure for ATEC. Most administrative personnel, budget accountants, and unfortunately even communication managers, are unable to grasp technical matters, and must see cost effectiveness in pure cost savings -- pure dollar reductions. Further, these dollar gains frequently can only be envisioned as personnel reductions. Personnel savings do result in reduced costs for a number of years vs. a one time cost avoidance savings. In the case of SYPAC, major technical gains and also major significant personnel savings are concomitantly achievable.

To attain these gains there are technical accommodations, but more importantly, there are major and basic operational changes required. These changes are needed both to provide the organizational framework to best achieve the technical performance gains available and also to reposition, restructure, and reduce personnel in line with the automated SYPAC structure. The changes required throughout the organization to meet these technical and personnel goals will be discussed in the following section.

The present concept of management of the technical mission of the command can be described by just one word -- 'Manual'. The measurements at the site, the link activities, the analysis at Gp, all are entirely manpower intensive and slow. Even at the Area and HQ where large computers

are available, and where much of the support effort is automated, the bulk of the technical direct mission related work is done by engineers with the support of hand-held calculators. The SYPAC concept will change this. The mission personnel have need for real time automated support at the lower levels, with automated, rapid reports and response to all higher levels. The following sections will contrast in some detail, the present mode of doing business, and the concept after the application of SYPAC to the command. Only slight detail changes will be required for use by the other services in the DCS.

Although there is some variety among the different DCS field organizations in the manner by which they organize to operate and maintain the communication system, there is still a basic underlying constancy. The following discussion is intended to explain generally the functions that occur at each organizational level. Any one who reads this concept report may find isolated examples that do not fit, but the described functions certainly represent the centroid of real life operational experience.

1.a. <u>Site, Node Present</u>

The bottom level in the communication structure is the site. The site can be an isolated communication place on a mountain top, or a work center on a base or station. The key identifying criteria for this hierarchical level is the fact that the site is 100% mission oriented. There is little involvement with formulation of long range goals, establishing policy, or broad mission management activities. Personnel on site are assigned to a

box, an assembly, or other highly constrained portion of the site hardware complement. Each man follows a tech order in accomplishing his duties that may be either operations or maintenance oriented. The goal is to keep all meters or other parameter indications within Tech order (T.O.) specified limits. Site personnel may be aware of the site mission, but normally see little relationship between their activities and the site mission. Unless site supervision is good, and that is notalways the case, some of the meter indications will be outside T.O. standards. There is little reason for each site individual to struggle to achieve high technical standards since he perceives no mission gain, and rarely does an individual or the site as a whole receive acknowledgement for premium performance. In fact, few managers can even recognize an outstanding technical job when it does occur, so they reward clerical and administrative activities.

The site supervisor normally sees his responsibilities as a group of boxes, or assemblies. If no box is defunct, no assembly out of operation, and nothing off the air, then he is content. Most site supervisors see only the most tenuous mission interrelationship of his site with other sites, or with the DCS -- unless his site is off the air. He then receives attention from everyone -- and has to prepare even more reports so he is conditioned to remember that he is part of a paper system.

This lack of total mission grasp is not too surprising. The technical training within the services is box and equipment oriented. The Air Force high level/management efforts to reorient the schools to the systems approach have not been effective. However, the recent arrivals of TEP engineers at the Air Force Schools may partially ameliorate this situation.

The detailed activities at a site can be described as measurement of parameters using built in or external manual test equipment. These readings are supposed to be recorded for subsequent checking by a shift or other supervisor. In practice many readings are not recorded, rather a check mark is made to indicate that the measurement was made and was "OK". The "OK" being the individuals personal assessment that nothing need be adjusted or maintained. This approach quite often by intent or by lack of technical grasp by the individual equals "pencil whipping". This pencil checking without benefit of meters is accepted by many technicians, since "if there were 'significant' problems, some customer would be complaining". Shift and work center supervisors who should catch and correct these illegal practices are on the day shift, and are fully occupied with administrative paper activites. Consequently, they never observe the actual PMI, or maintenance activities conducted predominantly at night.

After a major degradation or complete failure has occurred in some device and the site mission has been impaired, the site personnel attempt fault isolation. This is a higher technical level activity, and frequently demands the services of the mid-level non-commissioned officers -- this is nearly always staff or tech sergeant level. There will normally be one, and if the site is lucky, two highly competent NCO's to lead these technical actions including isolation and corrective actions. These few NCO's do not have time to do in depth analysis of recorded data and so concentrate on the immediate problems facing the site. The high level technical competence is almost never the top three -- chief, senior and master sergeant. These top three NCO's are , by personal desire, by direction of technically

unqualified commanders, or by the flood of administrative and clerical paperwork, tied to a desk and play little part in the technical mission of the organization. The unfortunate part of this trend is that the old sergeant, revered in times past who could fix anything and makeshift what could not be fixed, has all but disappeared from the military and will not be recreated.

Only in the tech controls is there presently any significant non-single site system oriented action. The PMP has forced at least a recognition that reciprocity on radio links is normal, and one noisy link degrades all the circuits through that link. Thus, in the DCS multi-site-analysis is slowly emerging. Some of the longer multilink group assessments have induced the recognition to some tech controllers that no one site is really independent from others from a mission standpoint, but this broader vista is generally restricted to few people, at the major nodes.

The deluge of clerical, administrative, and logistical activities are intended to be supportive of the mission. Unfortunately the integrated magnitude of all of the paper is highly detrimental and in the case of the top NOC's in all technical categories is nearly completely destructive to their basic technical functioning. <u>The concentration on paper about support facets of the mission has destroyed the focus on the mission itself</u>. There are many clerical positions that could be saved to free personnel for direct mission related activities, however, this approach has not been selected.

In summary then, present site mission related operation actions can be

categorized as below:

1. reading meters
2. measuring parameters at test point
3. making pre-set test setups and measuring results
4. recording results of measurements
5. review recorded data for 'something of interest'.
6. make non-prearranged measurements while troubleshooting and fault isolating
7. make reports on bypass patches
8. make hardware repairs and adjustments.

1.b. Site/Node - Future

In the SYPAC era, many of the personnel now assigned at the site to make measurements and perform PMI on the boxes or assemblies will not be needed. Most of the special test setups, requiring manual test equipment, highly skilled maintenance personnel and many hours of work also will not be required. As covered in the discussions on terminals and networks, built-in test equipment and self-performance assessment capability will permit many of these steps to be accomplished automatically, or will be sensed and reported upon demand to the major node or network control. The hardware 'in-service performance assessment' implementation can report its status as required. There will still be the need for repair action and periodic adjustments by technical personnel when the above indicators show something amiss.

The bulk of the routine measurements required under the various Quality Control, Performance Monitoring Programs, Fault Isolation can be

conducted automatically. Many of the presently required Q.C. tests will no longer be required since the in-service network signal assessment does much of the circuit job directly or indirectly, and more effectively. The task of circuit, group, or baseband, reroute and alternate route patching and minor special testing will still be required if some element of the system degrades or fails.

The endless recording of measurements by maintenance personnel whether needed or not will be greatly reduced, but more importantly the tabulation manipulation, and local level analysis can be approached automatically, as can the formating of necessary reports, for both local use and processing to higher levels. One of the major gains will be the ability to perform significant analysis automatically for direct use by the site personnel. Measurements will automatically be tabulated and compared against preset thresholds to alert maintenance and operations personnel of undesirable changes. Conversely, if all measurements indicate no degradation, many supportive measurements and rote PMIs need not be made. This is a key source of savings in manpower. The data can be processed for summarization and local storage and reference and for forwarding to higher levels.

In the long run, perhaps the prime gain will be the ability to store data taken from the maintenance activities as well as measurements taken from the tech control and to correlate between the two. For the first time, there will be the opportunity for maintenance and operating personnel to see portrayed the intimate interrelationship between maintenance of the pieces of hardware and the mission performance.

Under the SYPAC concept, the relationship will become clearer between the site performance and the operation of the networks and total system. The data interchange capability increases the need for comprehensive orderwires, but greatly reduces the need for personnel since no manpower will be required to cooperate in time consonance, for reciprocal measurement or for special testing.

One of the further opportunities for both personnel savings and concomitantly reduced skill levels relates to the SYPAC capability to sense small degradations early before any significant service degradation has occured. Thus enlightened, management will have the opportunity to get most effective use from the fewer needed maintenance personnel, while still achieving increased technical-mission performance.

There are two general approaches for reducing manning requirements at the site level. The first has already been described above and that is to first withdraw personnel concomitantly with the full addition of SYPAC to make the site unattended.

The second approach to achieve personnel savings at sites is to man the site with a minimum number of relatively unskilled personnel who can attend to site security, and respond to either local alarms or instructions from management, based upon SYPAC data. The technically demanding tasks can be under control of a highly competent central Group (not the present work load control office). Spare cards or other relatively inexpensive parts requiring little skill to install would be stocked on site. Only in cases of major equipment problems would travel to the site be required by the skilled technicians.

From a pure manpower and cost savings standpoint, the first approach is the least expensive overall, if the equipment is procured to considerably higher quality specifications and installed in accordance with much better quality control than present practice. In the late 1970's, continuation of the pressure to buy 'cheap' hardware is likely to be high due to the extreme fund pressures. However, countering part of this adverse status will be the arrival of SYPAC and the remote sensors that will at least partially compensate for equipment shortcomings by performance assessment and fault isolation capability. Thus, the likely realizable position will be a combination of both alternatives. For sites near a center of technical expertise an unmanned operation would be logical. For sites more removed from easy and quick road access or where the number of pieces of hardware is large, minimal and low skill level manning will be preferable. Highly isolated sites will need to straddle the issue and assign one or two more competent men.

The locations where the large switches are placed such as Autovon and Autodin are not classed as sites, but rather are major nodes and are the true fulcrum for SYPAC. The switch node is the heart of network assessment, including responsibilities not only for itself but also for the tails and bases accessing the DCS through it. Switches will have traffic flow and control activity, much of which could be done remotely from some Area control point in peace time. But a hostile environment will demand that some of the network operations be delegated to the switches with hardware and traffic status forwarded to the Area. The control thus can be centrally controlled, but decentrally executed and with semi-independent

operation based upon thresholds. Thus a viable graceful degradation operational capability can be attained.

As a result of these network needs, skilled personnel will normally be required only at the switch nodes and isolated sites. More will be said of this under the Group discussion. The site functions under SYPAC will be as follows:

1. Make a few non-prearranged measurements and adjustments.
2. Make patches and substitute equipment.
3. Insert spare cards or parts in hardware.

2.a. Major Nodes - Present

Presently a switch co-located with a major tech control is viewed only as a large site. There is no recognition of the basically different mission functions between a switch node and for example a Rf microwave site. A major node impacts directly not only on a single DCS element such as the backbone structure, but also network operations, base access matters, user terminal operation, etc. Clearly a major node is a different class of communications element. Nevertheless, a major node presently receives little special management attention, unique local supervision, or special manning considerations. It is classed as just another site and has functions nearly identical to that described in a Site-Present above.

2.b. Major Node - Future

The major node will be a key mission functional entity that will have a major role in the SYPAC era although not a discrete organizational level. The major node is a large tech control co-located with an Autovon,

Autodin, or other major network switch. These major nodes have existed for a long time, but have been considered nothing more than a tech control for the broad band structure node and with a switch located nearby. There was no mission relationship between the two co-located activities and no management connection. The synergism that will result in the SYPAC era was not recognized. There are two points however that must be made. The importance of the major node in backbone assessment and network control will be large under SYPAC. Since the major node will assume such importance, the decision to withdraw all officer technical talent from the major node must be reversed. It is mission important that competent young officers be assigned for training and also for active personal leadership of the major node functions. This young officer is required also to work closely with the Group Analysis and Control organization. This is really the lowest organizational level where true system activity and training can occur. This is the level where the future commanders must learn.

The functions of a major node under SYPAC include:

1. Normal site functions.
2. Direction of the tail access path assessments and control.
3. Direction of the base cable plant assessment and control.
4. Direction of the base terminal assessment and control.
5. Direction of the local portion of the network traffic assessment and control (decentralized portions).
6. Analysis of sub-portions of the Sector backbone structure and network inter-relationships.

7. Control of actions directed by the Sector within the major node area of responsibility.

3.a. Squadron - Present

The squadron is a management level having assigned responsibilities for a number of sites or work centers. Squadrons were originally considered to be a logical grouping of similar functions. The squadron was intended to encompass the mission for a constrained area, and was to include mission accomplishment assessment, resource allocation, support assurance to the sites, and supervision on all assigned responsibilities.

Events, however, have not progressed to the above ends. The squadron level organizations are by far the weakest in the entire AFCS chain from a mission standpoint. The squadron commander is often a non-technically qualified officer with little training or understanding of his mission task. He has been taught by the service schools that his job is 'management', but the courses he has received are predominantly administrative. He has been taught that his NCO's will take care of the mission and that he need not be technically concerned. This lack of mission grasp by the commander assures that the effectiveness reports for young officers and NCOs normally give recognition for accomplishments related to clerical functions. Thus the lack of mission grasp through the operation is not only self-perpetuation, but actually degrades the total technical competence of the command. Even more disruptive, the advancements go to those who concentrate on paperwork and never have delinquent reports.

This indictment does not mean that mission matters are not addressed at squadron level, but it does state that the bulk of the time of the officers and NCO's at this level are fully spent on matters not closely related to the mission. This distorted status is not likely to improve since even non-related mission functions now are being combined in one Squadron 'to save people'. In all candor, it would be nearly impossible for even a highly competent young officer to really command a combination of base, backbone structure, installation, and flight facilities activities. The various HQ's all have been party to this furthering of non-mission focus by a flood of 'special matters' correspondence. More than 100% of his 8 hour day can be spent on distal paper business. A few rare squadron commanders have 'bootlegged' a first sergeant who conducts the bulk of the paper efforts, so that the commander can exercise command.

The working level personnel address logistic, personnel, and other functions that do support the sites, but perform these actions, largely out of any total direct mission context directed by the commander.

The average Squadron that has responsibilities primarily for flight facilities is generally better,more knowledgeable and involved in that mission. The Squadron commander and the flight facilities officer frequently have had a direct or supportive role in some flying activity and so are technically competent to manage and command that mission. Most personnel in the direct support to flying activities recognizes that 'out of tolerance' conditions require a 'Red' rating and a report all the way to HQ AFCS and understand that continued 'Red' operation can kill people.

Both of these factors generate mission sensitivity. In communications, such clear and unambiguous connections with the mission is rarely evident.

The Squadron maintains an NCMO (Navigation Communication Management Office) co-located with the box oriented logistic work load control function. The NCO staff for these offices were removed from the technical staffs of the sites and the squadrons. The original goal of the NCMO was to center mission management at the lowest level where direct and constructive assistance could be applied under the direct perview of the commander. In practice, it is a place where the commander and his staff come once a day to hear a rather sterile version of yesterday's problems. (Cleaned up because all organizational elements have to coordinate on the semi-formal script). The NCMO impact thus at best is not energetic nor incisive, and has become predominately a report assembly and forwarding office. The original NCMO concept is a needed one but it must be reformulated in the originally desired form to become relevant.

The mission operational activities at the squadron can be summarized:

1. Logistic support for sites.
2. Administrative assembly and forwarding of the site technical reports.
3. Operate the NCMO report assembly.
4. Report outages to higher HQs.
5. Prepare clerical reports.

3.b. Squadron - Future

Under the SYPAC concept the Squadron will still have little Communication mission management activity, but this lack of contribution will be formally acknowledged. The squadron will be a communication support activity. It will be a convenient location to house and ration personnel, to service and repair vehicles, or coordinate and support PMEL, etc. It will be managed by an administrative office. If there is a base telephone system or other base communication entity, it may assume these O&M responsibilities, but not independently. The base, as explained earlier in the backbone section, is an integral part of the backbone structure. Thus, the base communication activity will be under the direct technical perview and management of the Group. Viewed from the Group level, the base in this case is a 'site', and will accomplish those functions as described under the Site write up. The intent is to tie the communication system together by reasonable regions. Where the communication activity cannot justify a Group organizational structure, a communication Squadron covering the area could be envisaged, but for this discussion, this type organization would function as a small Group.

Obviously, the above discussion leaves unchanged the flight facilities responsibilities and, in fact, will now permit more focalization of management attention by the Squadron personnel on such flying related activities. The Squadron management can assume a greater role on the Communications Electronic Staff Office (CESO) type actions for the base occupants, and act as communication liason to the Group. Obviously, the

Squadron would operate and maintain any special command posts, etc. and related special command and control activities. On-base equipment such as communication terminals and assemblies that form a part of a network could well be maintained by the Squadron, however, the operation and maintenance of the terminals or other parts of the system will be under the operation control of the major node and Group or the network controller.

4.a. Regions/Group (Sector) - Present

Several years ago, the Air Force communication structure had an organizational level called a Region. It was responsible for a geographical area. The Regions were deleted during an arbitrary reduction in the number of HQ levels directed from AF. The goal was the saving of personnel by elimination of one level of management. On paper the Region seemed to be a superfluous entity between the squadron and the Area. In practice it was the only level where significant analysis and correlation of information and mission management took place below HQ AFCS. Nevertheless, the Regions were killed.

Since the Area cannot and should not have been expected to manage the Squadrons directly, a new organization was created beneath the area, but not over the Squadron level and with a modified structure and mission. The new organization is called a Group and is classed as a direct mission element while the Region had been classed as overhead. The Groups were structured by gathering similar broadband functions under one management in Europe. In the Pacific, the Group was created as a conglomerate that had many diverse responsibilities assigned to save overhead personnel. As a

result, the Pacific Groups have little mission relevance or impact.

The Region/Group in Europe has a clear mission function -- the management of the backbone structure in a geographical area. The area of responsibility permits assembly of information from numerous sites with similar equipment for comparison and analysis. The DCA 'Sector' designation is functionally the same hierarchial level. The effectiveness of the present Air Force Groups, however, was partially frustrated by an administrative decision. Figure 6-1 is a portrayal of England, presently assigned to one Group and 5 squadrons. The Squadrons are assigned one to each Air Base.

As can be seen in the Figure, the Group has direct responsibilities for most of the territory in England in this typical case. Most of the backbone structure sites are assigned and directed by the Group, except for those sites located on base. The Group also has responsibility for three major communications nodes and the associated tech control. The backbone structure sites co-located with the Squadrons report to the Squadron commander using the clerical logic that two AFCS organizations should not be on a single base.

The circles in the bases represent the base cable plant that forms a part of both the backbone structure and on base interconnect. Thus it serves both an inter and an intra base function. The base functions even though clearly part of the communication structure do not either report operationally or even inform the Group on problems experienced on Base that might be common to both.

Under the present scheme, the Squadrons report directly to the Area. Since the technical competence is low at the Squadron, their reports of

TYPICAL GROUP TERRITORY
England

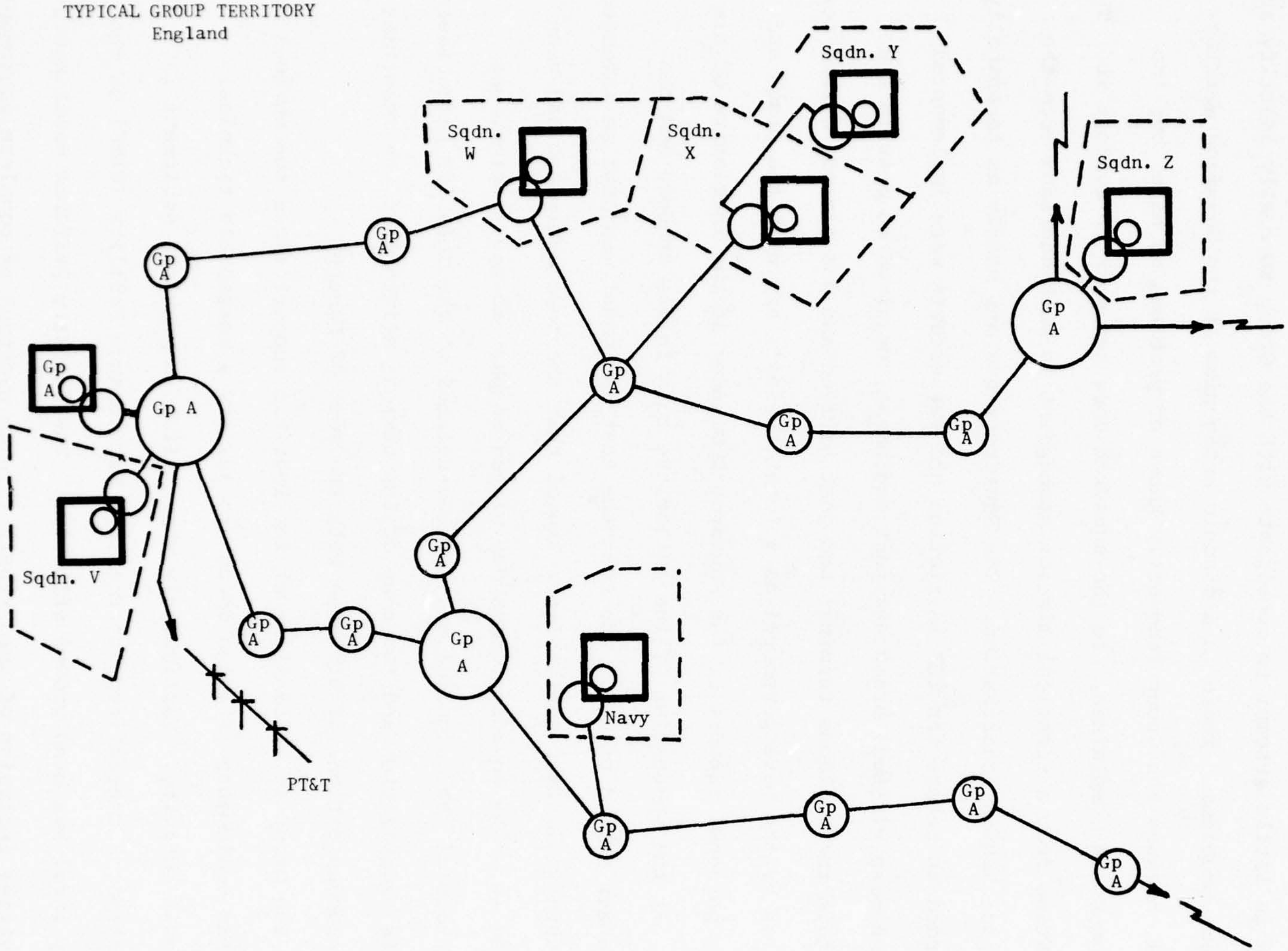


Fig. 6-1

problems are routinely superficial, not based upon measured data and most often a typical response "problem is not here, try the backbone circuits." There is little attempt to coordinate with the Group to really identify and correct problems. There is a chronic antagonism at the Squadron working level, because the Group frequently knows of problems on base, but 'no customer has complained,' so the squadron does not work to correct it. The situation from a technical mission standpoint is much degraded from the previous Region organization. The Squadrons now are nearly as technically retarded as before the TEP initiation and PMP efforts were implemented. At one base visited, brand new test equipment, required to operate and maintain the backbone terminal had just arrived and was already marked for turn in by the base personnel as a 'cost saving', and with the proud and happy personal support of the Squadron Commander at the initiative of his men. At the suggestion of the author,the turn in was stopped and the Commander stated he would see that the test equipment was used as intended. A return visit four months later showed that the test equipment had been turned in. The Squadron commander played no part in the mission, was oblivious of the technical mal-actions related to the inferior performance of his organization and saw none of the obvious evidence of the resultant poor communications of his base with the rest of Europe.

The Group is an ideal level for logistic support since the numbers of similar equipments is large enough to justify a reasonable technical analysis activity. Particularly where offshore procured equipment is installed, a Centralized Intermediate Maintenance Facility (CIMF) at the Group level has been proved effective. The facility performs maintenance activities inclusive of card repair through overhaul of complete equipment.

The Group also operates an NCMO with responsibility and goals of premium performance for the assigned backbone structure and some Groups approach the desired goals. Unfortunately the Group is never assigned the last portion of the backbone structure on base. Thus the structure works well up to but does not include the last drop.

The Group of course has its fair share of administrative and clerical paper workload, but in Europe, at least, has reasonably well mastered both the mission and the paper responsibilities.

The mission operational activities at the Region/Group are enumerated:

1. Operate an NCMO
2. Manage the backbone structure in a limited geographical region
3. Provide logistic support
4. Operate a CIMF
5. Report to Area on status of geographical region.

4.b. Region/Group (Sector) - Future

Under the SYPAC concept, the Group will assume the lead communications mission role within the command. It will not be a policy headquarters, nor an administrative one, but rather a full time working organization, streamlined to provide only the needed skills to operate and maintain the communications in a geographical region. High technical skills will be needed to operate and maintain the sort of a communications entity, presently under development by the DCA. The future DCS will be complex, highly

automated in many of the network services, high speed on much of the record traffic, and carrying the highly centralized command and control networks required to meet the range of conflict from all out war, to small or medium scale brush fighting. The Group command and direction of such an involved structure cannot be by passive reaction to customs complaints but must be based upon an in-depth grasp of the true system status. The SYPAC mechanism will sense the needed status by gathering information from all relevant hardware, assemblies, circuits, including the network signals traversing the area assigned to the Group, and provide the Group, DCA Sector, for the first time a system performance assessment and visualization.

SYPAC then will analyze all information in accordance with logic and algorithms to be programmed into the computers throughout SYPAC. (Traffic data will also be sent to DCA.) It is clear that SYPAC will be helpful in the 1970's even with the older plant in place, and the system and analytical algorithms will first be tailored to that vintage hardware and the equally unmodern organization. As new hardware can be procured in line with the SYPAC concept, as organizations can be restructured to meet the mission needs, as training of personnel is modernized and as the sensing of hardware, terminals, the backbone structure and the networks can be expanded, then the software will be incrementally expanded, made more comprehensive, and the analysis at all levels will be widened and increased in sophistication. The software will be an ever molding effort providing ever greater assessment analysis and data for control.

The people to staff the technical slots in the Group will require

special selection, just as the crew of the F-111 or the F-16. Crews of these aircraft are all especially trained to handle this very important mission -- flying a complex machine and the personnel computer recognizes this fact and does not name a clerical or administrative officer to 'manage' the airplane. The Group personnel also 'fly' a complex machine composed of electronics far more complicated than the present equipment. Engineers and technicians of equivalent training and experience to the TEP teams will be required for most technical positions. These Group personnel will have at their disposal all of the measurements, the tabulated data, analysis results, and capability to query and make special tests, and are provided all the traffic sensed information. All this cannot always be neatly packaged in form for consumption and understanding by administrative personnel, although much can be so reduced. Thus, there will be a requirement for a significant percentage of skilled technical personnel for key jobs at the Group. However, since the sites and squadrons no longer have the need for such skilled personnel, the total AFCS requirement for highly skilled personnel should be less -- but only if the Group is properly manned. (Flight facilities personnel needs remain unchanged.)

There will be a need for highly skilled engineers and technical analysts to examine the reports provided by SYPAC and to convert these data to recommendations for the Group commander. There will still be the need for management decisions on resource allocation,on the dispatch of skilled maintenance men to a site,or the attempt remote control repair using on site personnel, whether the degradation is sufficiently rapid so as to

require emergency dispatch of resources or whether the corrective action can wait a normal work day, etc. The Group commander must still manage, but for the first time he will have the data and technical personnel to permit him to 'command.'

The SYPAC concept of operation for the Group is portrayed in Figure 6-2, the geographical region used earlier. The backbone sites still are assigned to the Group as are the major nodes and tech control. Now, however, it is both viable and mission essential to assign all backbone sites geographically located on bases to the Group. The personnel assigned will be relatively low skilled as explained earlier, and will take all operational guidance and direction from the Group and all reports will be to the Group. The men, if any are assigned to a site, may be attached for rations and quarters to the Squadron. This old ploy will avoid the two organization clerical difficulty.

Further, the base phone exchange and the base cable plant form an integral part of the backbone structure when viewed user to user, so they too must take operational direction from the Group and report to the Group. There are a few cases where the base cable plant supports on-base users and do not interconnect with the outside world. This exception,however,is an important one and includes the interconnect lines among the flight facilities and air traffic control functions, etc. Administrative people will argue that if the flight facilities are to be handled as a system all elements must be considered,therefore flight facilities on the Base must control those special interconnect lines. Administratively, they are quite correct, but cable plants, under the Squadron are <u>not</u> quiet now. Technically, if the

SYPAC Group/Region Responsibilities

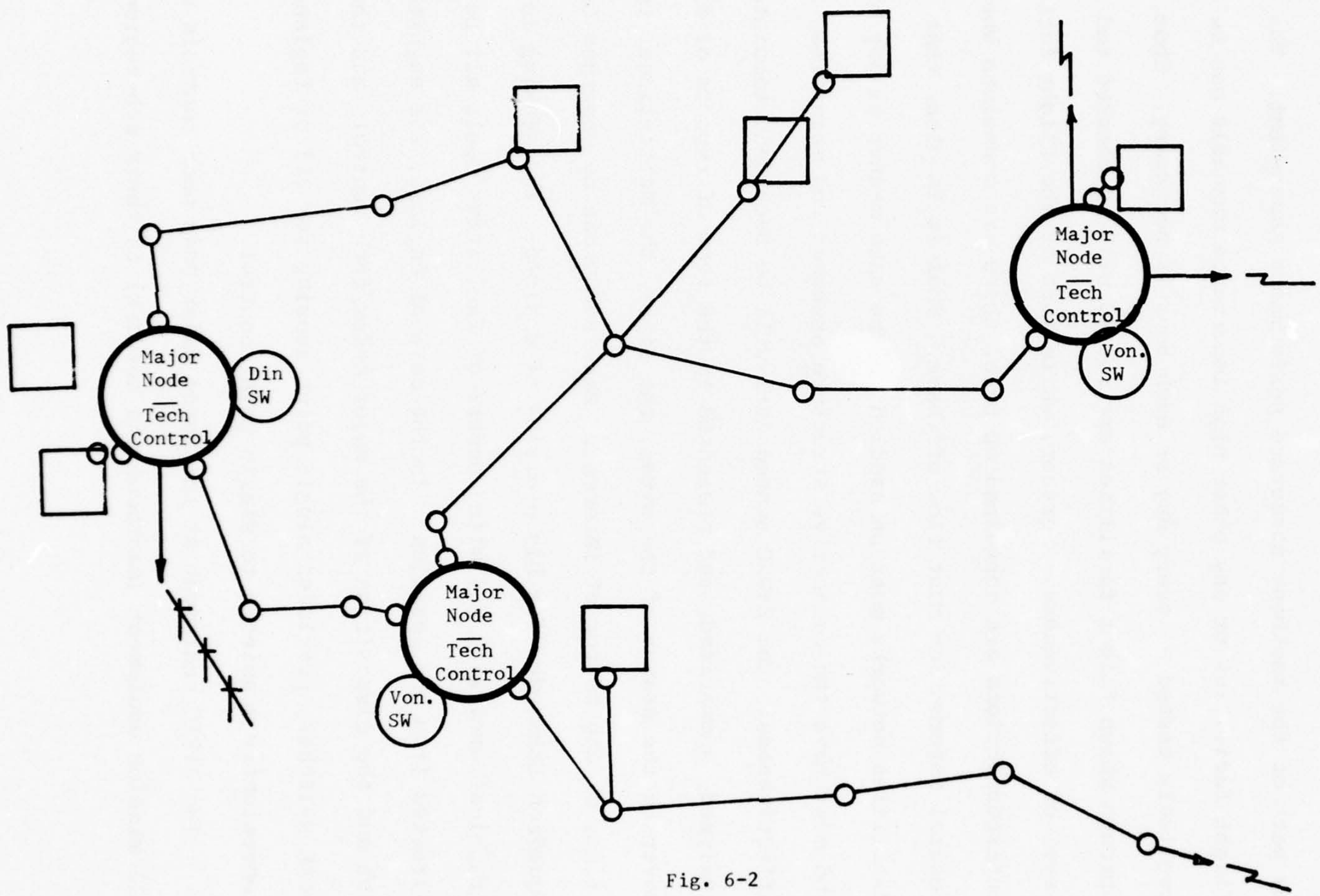


Fig. 6-2

cable plant is quiet and introduces no disturbance to the DCS, it will not cause trouble to any flight facility communication, thus, the issue is entirely specious. As has been described earlier, SYPAC -- and ATEC has already demonstrated this capability -- will routinely assess the cable plant as part of the backbone structure performance assessment. The special flight facilities or any other high importance channels can be routinely and precisely tested -- every day or each hour if necessary. Thus, the cables through which flight facilities are routed will be checked and at a high level of effectiveness. Further, while much of the flight facilities interconnections are contained on base, there are occasions where air traffic control information must flow off base. Thus it is clear that flight facilities networks must be handled in the same manner as any other net and must have the connective structure assessed and maintained at peak effectiveness. The SYPAC sensed data will be recorded, tabulated, processed, analyzed, summarized, and presented in the form of reports or displays covering the status of the sites, the links, the multi-links, the base plant, or any matter of interest. Base status can be provided to the Squadron Commander for his overview if desired. The sensing in a geographical area with a limited number of facilities could all be sensed and directed from one location. In the case of England, the magnitude of the job and the disposition of the major nodes/tech controls and the major network switches, precludes single point sensing for all of England, but will conveniently acquiesce to single point control.

The SYPAC equipment at the three major node tech controls will sense all mission equipment (backbone and network) in their sub-region,

as indicated in Figure 6-3 and will operate those functions unique to the sub-region, and will pursue these tasks independently from the other two sub-regions. In matters crossing the boundaries of any sub-area, the concerned major nodes will exchange data and measurements as required to resolve the problems jointly, with technical overview by the Group. If the problem is serious, in that it violates some preset threshold or other management criteria, a report will be required to the Group (and perhaps higher). This will be automatically framed at the major node with human intervention required only to approve the report for release.

The Group HQ was placed adjacent to one major node for reasons that are logistic, cost and housing related, however, the SYPAC concept can meet all mission needs with flexible Group geographical placement constraints.

The three major nodes are all tied to the Group automatically by data orderwires, and also by voice orderwires as indicated by Figure 6-4. The major node to major node direct orderwires are also indicated to accomplish the necessary lateral interchange of voice and data necessary for link, multi-link, and network correlation. A superior SYPAC processing element is located at Group (Sector). The key point is that although each major node pursues assessment of the bases, hardware and links assigned to it, the Group at all times has both status and direction of the entire region.

5.a. <u>Area - Present</u>

The Area organizational level, in the past, has been one of the keys

SYPAC Group/Region Sub-allocation

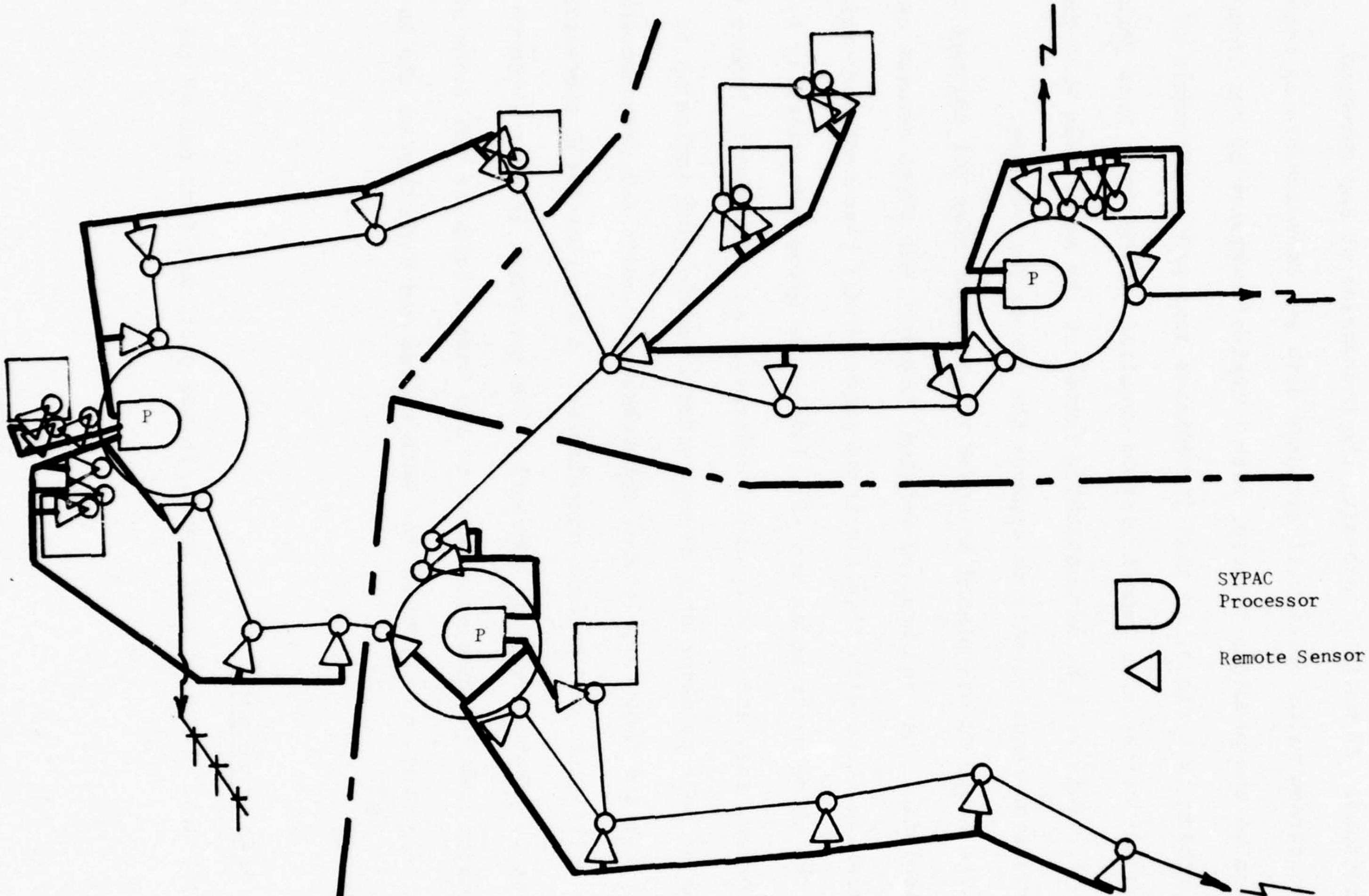


Fig. 6 - 3

Group/Region (Sector) Processor Integration

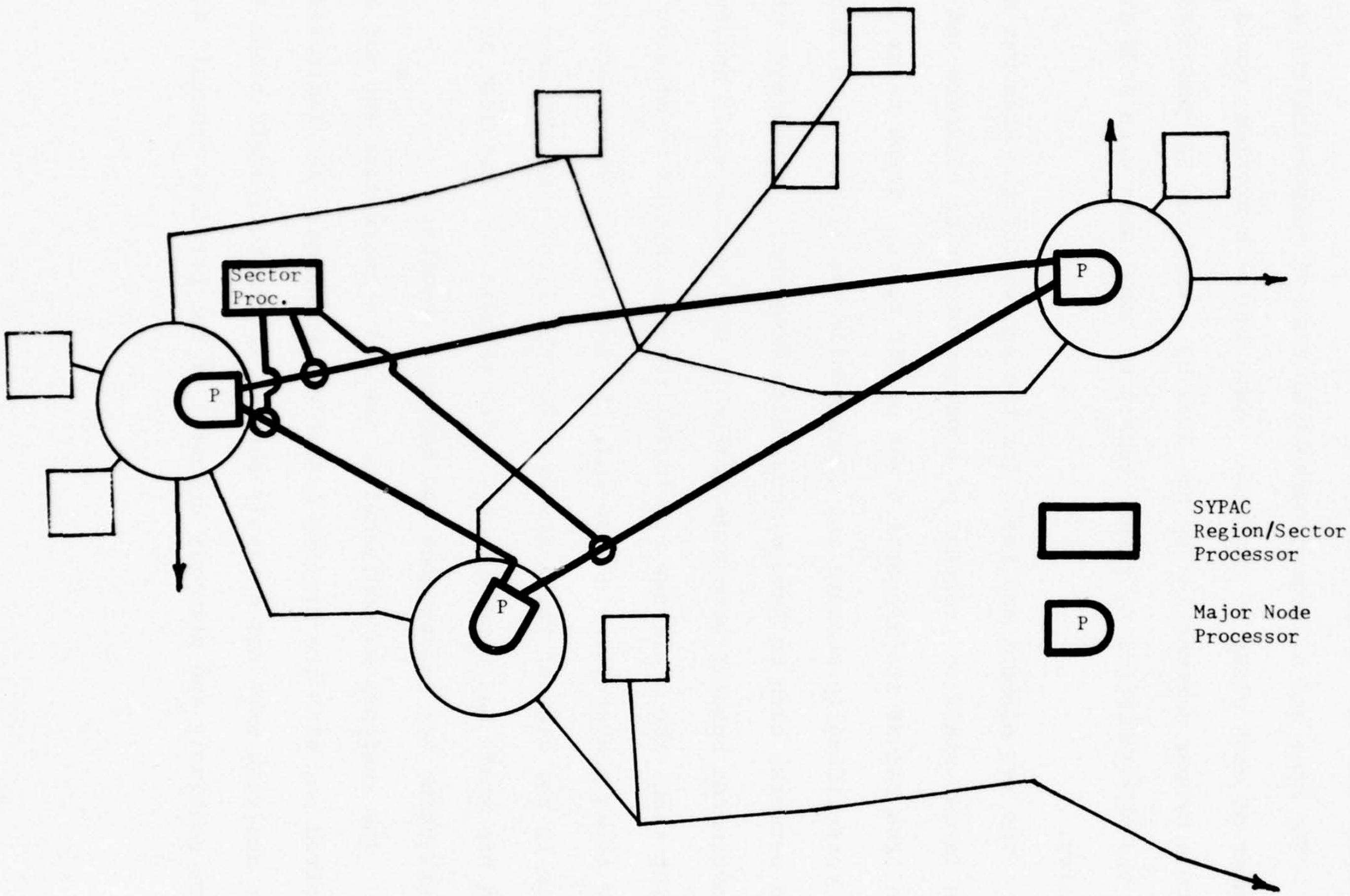


Fig. 6-4

to successful management and direction of the communications system. It was at this level that the NCMO performed its most constructive role. The commander was normally a general and he had an adequate staff to perform at least minimal analysis and follow up.

The Area had a large geographical area of responsibility with a large number of each class of hardware. Some logistic problems could be placed into a proper perspective by the Area HQ. The Area HQ conducted training of the Regions/Groups to assure technical compliance with AFCS direction and policy.

The key element and basis for the success of the Area was not entirely the larger staff or presence of a number of senior officers and NCO's. The Area had at its disposal a set of TEP teams. These teams were assigned to scientifically measure and characterize the sites, links, and multilinks and networks such as Autosevocom, High Frequency, ground/air, etc. The TEP measurement results were made available to the area staff and for the very first time, the staff saw meaningful results related to mission performance. TEP teams measured the end to end, the integrated performance of the system. This is the view of the customer. For the first time the Area commander and his staff had system facts. TEP results were not lost in the maze of conflicting box maintenance and logistic reports.

The analysis accomplished on TEP and network data was not in the depth desired nor with the breadth possible. Frequently the indicated actions of the analysis were not actively pursued by the full staff since the results were routinely and strongly critical of the previous 'normal' staff actions.

The heart of the analysis effort was the personnel who conducted the TEP. These were, by and large, the only people with sufficient in-depth breadth and technical grasp to understand the mission and to perform analysis in any way directly usable by the commander to improve system wide performance.

The above relatively favorable picture, however, was recently severely impacted by HQ reductions and the Area now has dropped much of the previous communication management activities.

The most recent HQ size reductions represented 'across the board' cuts with little technical consideration of details of system management and the key mission elements suffered greatly. However, the mission responsibilities prior to the cuts are summarized below:

1. Support the area Air Forces
2. Manage a large geographical area
3. Provide logistic support
4. Report to HQ AFCS
5. Operate an NCMO.

5.b. <u>Area - Future</u>

Under SYPAC, the Area still has a role in the successful operation of the system. The Groups now can really handle the day to day technical job completely. The prime Area mission function now is much more oriented to coordination and support of the Air Force component commands and communication structure planning.

Data on system status must be provided to the Area commander so that he will be in a position to make those policy, planning, management, or resource decisions required - and now he can really see the status of his Area. This restructured Area HQ mission staff can be smaller than it previously was because of SYPAC analyzed status inputs. Further, the structure planning and command support mission accomplishment can be considerably better because it will be based upon measurements unbiased by unit self-reporting and self-evaluation. The commander and the staff can change decisions if they prove, after field implementation, to be less than optimum as measured by SYPAC. A true feedback control scheme operation.

6a. HQ AFCS - Present

The HQ is responsible for the complete operation of the command. This responsibility has been actively pursued using all available data, analyzed to identify problem areas. With other commanders it was passively managed, reacting only to major problems. The latter approach is the one that characterized the command up to about 1965. The active concept was first attempted in the mid 1960's but met with limited success because it is not possible to analyze command problems without quantitive data related to the command mission. In 1966, there was no such measured mission data. In 1966, the concept was born that resulted in the TEP approach. The command in 1968 began to assemble measured data on large sub-elements of the DCS system. Later, the concept was expanded to encompass selected networks such as Autosevocom -- DCA called this effort JAEP (Joint Autosevocom

Evaluation Program) -- and others.

The command set up a Directorate of Systems Evaluation to be the prime command location for the gathering and analysis of the TEP data. The rather frequent shifts in the Directors, the rapid turnover of the TEP engineers and technicians, and a general lack of technical competence by much of the HQ staff including civil service at most levels, caused the technical progress to be slow, and the analytical processes even yet are not well developed. Nevertheless, some basic policy analysis concepts were developed in HQ for application in the field. The 'Blue'book by European Comm Area is one example.

Additionally, the concept for the Performance Monitoring Program (PMP) was devised and implemented by HQ AFCS, as was the Mystic Star, Ground/Air/Ground, and the Tracals TEP type programs.

As the Area staffs were decimated, HQ AFCS picked up more of the detailed analysis from the Area, although not in the depth achieved by the Area. Analysis presently in the command is marginal. Cuts in HQ AFCS staffing means that the previously used primarily manual methods of data reduction and analysis cannot be sustained in the future.

The mission technical data, along with appropriate administrative, logistics and other support information is presented to the commander and his staff for use in management. The command also has literally thousands of reports to generate, assemble, process or otherwise forward to HQ USAF. Some of these are related to the mission. The AFCS has all of the standard activities and special staff offices of any major command.

The HQ functions are well known from reading AFR 23-32 "to provide, operate, and monitor communications and flight facilities, and to provide air traffic control services for the Air Force and other agencies." This is not exactly a full specification of HQ activities, and commanders meet these responsibilities in many ways -- some actively, some passively. However, what ever the bent of the Commander AFCS, all major mission technical innovations to date have been devised and directed from the HQ. Although all ideas certainly have not surfaced only there, the HQ must formulate the ideas into viable policies and procedures for use throughout the command. The heart of the command management is supposed to be the NCMO/MIS (Management Information System). If the command HQ has no viable flow of data to give current mission status, staff actions are likely to be unrelated to real missions problems. If the command HQ is completely immersed in mission details, some people view this as using a '6000 mile screwdriver'. There is strong aversion to this centralized control. Part of this reluctance is based upon the inability of these personnel to understand the technical data that traverse the NCMO (Navigation Communication Management Office) reporting chain untouched, unanalyzed, and replete with errors and omissions. Often the data is approximately correct but incomplete and requires an in-depth grasp of mission and technical operations to translate. This reluctance to analyze technical data is in part a cover for the inability to grasp the mission impact of the data.

The second reason for opposition to the 6000 mile fix is completely valid and encompasses the logic that the sites, Groups, and Areas should

do their job and the HQ should give report cards on how well the job is done. Constant HQ actions preclude such evaluation. However, a true evaluation of the field units must presuppose a HQ staff that can both understand the field job and also can correctly assess how well it is being done by examining parameters that measure the mission accomplishment, and can watch these change and judge the performance. This latter approach is not yet possible. The HQ reductions, the lack of sufficient technically competent staff personnel and the present funding environment make the command management difficult and largely 'reactive.'

6b. <u>HQ AFCS - Future</u>

Under SYPAC the HQ task of directing the command activities can be based on facts, and measured status. The HQ has already started to accommodate to some measured data, such as that resulting from the PMP program and the TEP efforts.

The System Analysis function will be even more necessary but now can be effective, with routine and accurate measurements from all over the world provided on a suitable time scale. The outputs of the analysis will be aimed at critical current and mid-range corrective O&M actions, and long term planning activities. HQ can assess the Areas responsiveness to current problems, and check the fields reaction to command directed actions. No longer will field compliance have to be assumed.

The mid and longer term planning with SYPAC can be based upon accurately measured capabilities. No longer will the wrong facility be replaced, or good equipment removed because of age when the problem is

poor operation or inferior maintenance. The justification for needed overbuilds and equipment changes can be factual and supported by measurement and operational results.

There are numerous examples of such costly mistakes, including replacement of a long multi-hop radio structure when the real problem was the noisy multiplex; replacing 'bad' multiplex when only a few mixer diodes had degraded; and the replacement of whole tropo links because of a bad modulator, discriminator and parametric amplifier. TEP prevented the wholesale replacement of the TRC-97 'because it could not meet service needs' by establishing a few simple tests to be performed in garrison prior to deployment. The three service 'Scope Creeking' of the Autosevocom network resulted in a 10 fold increase in net performance, not by replacement as had been planned, but by correction of design mistakes still undetected and unknown 6 to 10 years after installation. Clearly planning as it had been practiced prior to TEP was very poor, and until SYPAC is installed it will still be marginal. Most gross mistakes now are prevented, although there are numerous examples of generally excellent equipment being scrapped when only a small portion of the total assembly is marginal in performance or difficult to keep in alignment. Product improvement can be highly effective, just as it has in the aircraft business. Aircraft are not replaced because one bracket cracks. Electronic devices should not be replaced either, when but one inexpensive sub-assembly needs improvement, but this presupposes a thorough understanding of the device and its performance in the system. Such has not been the case. Prior to TEP inferior performance was rarely reported.

After SYPAC, selective product improvement should be the rule.

Furthermore, the largely unproductive and excessively time consuming maintenance/logistic reporting can be massively overhauled and made relevant. Clearly the SYPAC posture is where the HQ commander and his staff have all mission assessment data, presented in only the detail so that: the assessment results are clear, the problem areas are highlighted, the organizations doing the mission well are identified, and those failing to meet acceptable standards are also spot lighted. The command then can solve the problem of differentiating between a good, marginal, or bad organization, and apply appropriate recognition, or corrective action both to the organization and to the personnel responsible.

7a. DCA - Present

DCA is responsible for overseeing the operation of the entire communication system. Presently such supervision is passive and normally consists of reviewing a series of reports generated periodically by the services.

Most of the reports are initiated at the sites and cover the backbone structure. The data goes directly to the DCA Region. These reports are highly detailed and require considerable analysis to extract anything of value. The site reports are filled with errors and are incomplete and present DCA with much the same problematical view of the broadband structure as is given to the services, and no meaningful data on the networks.

The DCA gathers peg counts from switches and network terminals, and assembles traffic flow data on a sampling basis infrequently. The sensors are amenable to spoofing so can probably fake data. Thus the network management is non-real time and suitable for slow molding of the network at best.

Thus, DCA is predominantly concerned with the backbone structure in duplication of the Air Force and Army efforts; yet there is presently little else they can do -- there is negligible meaningful data available on the operational performance of the networks or the system.

The DCA has a limited number of skilled engineers who visit sites or switches and observe or otherwise ascertain what problems may exist. These engineers, however, cannot go to the depth of a TEP team for time reasons and so the DCA personnel function more akin to an IG. Of course, the DCA Area and HQ face a plethora of other functions, but the above addresses the direct mission responsibilities.

The HQ DCA is struggling to formulate the overall plan and system engineering concept for the future and has even a greater need for in-depth and precise data on actual system performance. DCA, like the services, is operating on a certain amount of intuition, false data, and outdated experience, but must continue to do so until the full automated reporting of SYPAC is implemented.

7b. DCA - Future

After SYPAC the DCA Area and HQ DCA can address squarely the prime

function that should be managed by DCA. This function can only be handled at a DCA Area or higher and cannot in general be handled by any one of the services. This function is the real time system structuring and network traffic management. Networks normally transit the facilities of all three services and the users are not only the three services, but DOD, State Department, Allies, etc. As a result no single service has the necessary breadth of control, source of data, organization structure, etc., to handle the task unless specifically assigned to one service in a limited area such as Alaska. Even in that limited area, the Air Force is handling a DCA function.

After SYPAC, the DCA can concentrate on the system mission, and assuring subscriber communication satisfaction. The sub-elements of this control includes, but is not directly concerned with the hardware health of the backbone structure, switch, terminal status, etc., or all the other parts and pieces required to serve each customer. DCA does not need complete detail on all parts that are operated and maintained by the O&M services. Rather, they need the status of all these elements. If all elements are 'like new' then no further information is needed. If conditions are marginal or degrading in one section of the backbone structure, then DCA will watch and pre-plan alternate actions and paths to use in case of further degradation. If the service responds expeditiously to correct the problem, DCA has no active role to play. If problems persist, the DCA system manager must play a more active part.

Nothing in the discussion is intended to state or imply that any

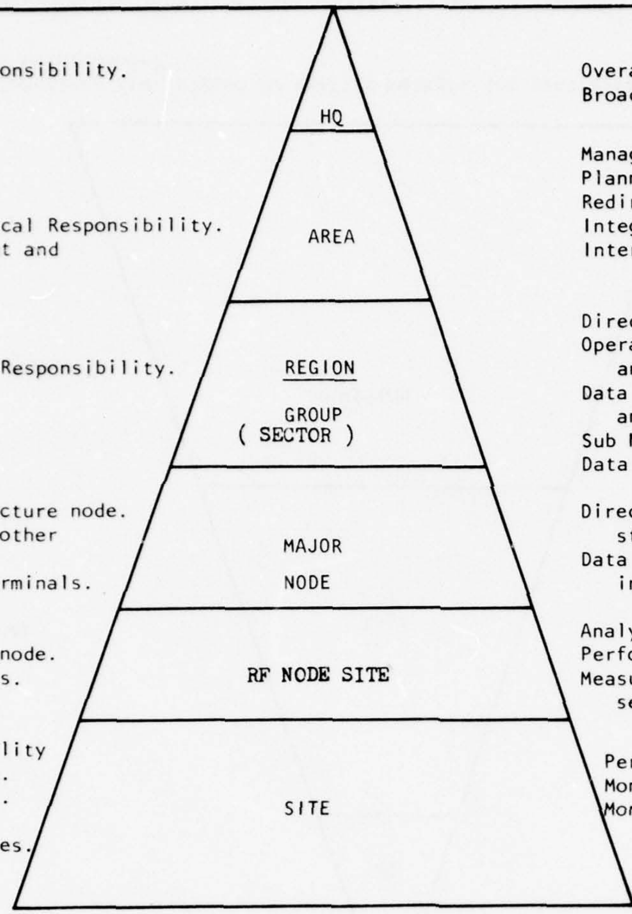
information in any part of the system, whether related to hardware status, maintenance actions in progress, traffic flow, or trunk usage, is the sole and proprietary possession or interest of either the Air Force or DCA. The key point is that if the O&M agencies have all of the hardware components of the system 'like new' then DCA need only know this in order to work on the system service issues. If the hardware is degraded badly in a locale, additional -- but not all -- information must be provided to DCA in order for them to pursue their goals. Conversely, if the hardware is normal -- less than like new, but above marginal -- and some portion of the networks are highly stressed and failing to provide adequate subscriber service, this fact is not the sole interest of DCA. Status, but not necessarily all network information, must be provided to the Air Force or other O&M agency so that they can apply their resources to optimize hardware and operations to relieve the stress in the affected region.

The appropriate functioning of the Air Force and of DCA and the proper responsibilities between the two is portrayed in Figures 6-5,6,7 and 8.

Figure 6-7 shows the flow of reports upward within each organization. Obviously, there will be some downward communications including both technical direction and instructions, and requests for added information or clarification of normal report data. The chart also shows only upward flow of hardware status to DCA, along with the appropriate network data. Quite obviously network control direction will be sent in the return direction. Some DCA instruction might come to the Group if

SYPAC

AIR FORCE ORGANIZATION



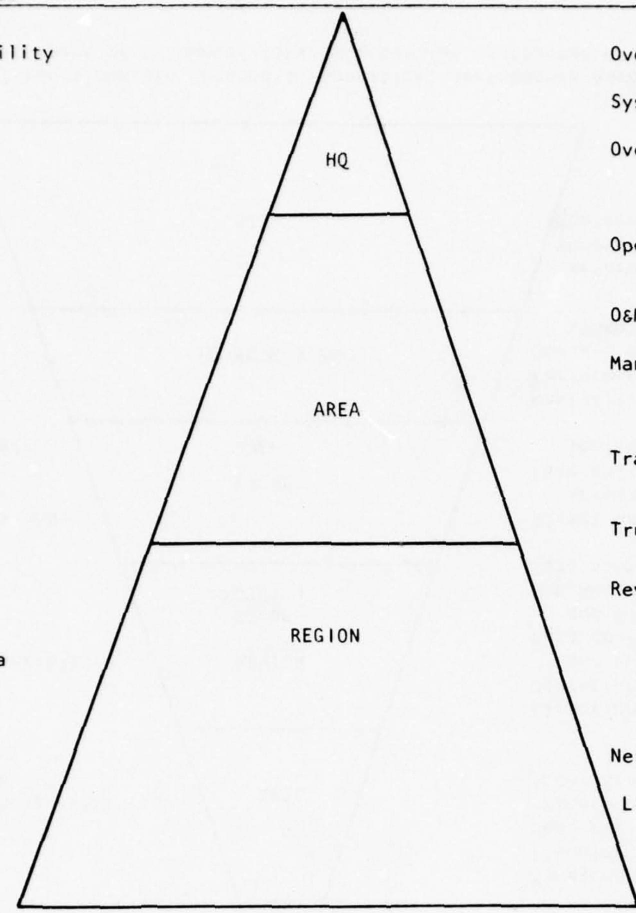
Responsibility	Level	Functions*
Overall Command Responsibility.	HQ	Overall management. Broad Analysis and Planning.
Large Area Geographical Responsibility. Support for Component and Joint Commands.	AREA	Management of Area. Planning Redirection of major resources. Integrate Region/Group reports and status. Interface with DCA on network problems.
Region Geographical Responsibility.	REGION GROUP (SECTOR)	Direction of total Region backbone structure. Operational direction of base cable plant and switch. Data collection, reduction, full analysis, and distribution. Sub Net assessment Data summarization, storing, and reporting.
Major Tech Control. Major backbone structure node. Multi-hop links to other major nodes. Network switches/terminals.	MAJOR NODE	Direct operations of backbone and network structure assigned to Major Node. Data collection, reduction, analysis including switches.
Tech Control. Backbone structure node. Links to other nodes.	RF NODE SITE	Analysis. Performance Assessment. Measure circuits, monitor alarms and sensors.
Patch and test Facility Radio, multiplex. Auxiliary equipment. Terminals. Electronic assemblies. Base cable plant/ base switch.	SITE	Performance assessment. Monitor alarms. Monitor sensors.

*All functions are related to operation, performance assessment, maintenance, or support of hardware/links/switches (as contrasted with traffic matters)

fig. 6-5

DCA System Control

Responsibilities	Functions*
Overall System Responsibility	Overall management of entire system.
	System Planning.
	Overall Network broad direction.
Large Geographical Area	Operational Direction of System (within area).
	O&M Agency Operational Evaluation.
	Management of networks including traffic control and network restructuring.
	Traffic data collection, analysis summarization and reporting.
	Trunk and circuit allocation and control.
Limited Geographical Area	Review of O&M Agency hardware status a. b b structure
	b. Switches
	c. Terminals
	Network sensing
	Limited network analysis



*All direct functions are related to traffic matters (as contrasted with hardware/links/switches operation or maintenance)

Status of hardware/links/switches/terminals, etc., will be examined if relevent to net or system performance

FIG. 6-6

GENERALIZED PERFORMANCE ASSESSMENT DATA FLOW
(Control follows reverse path)

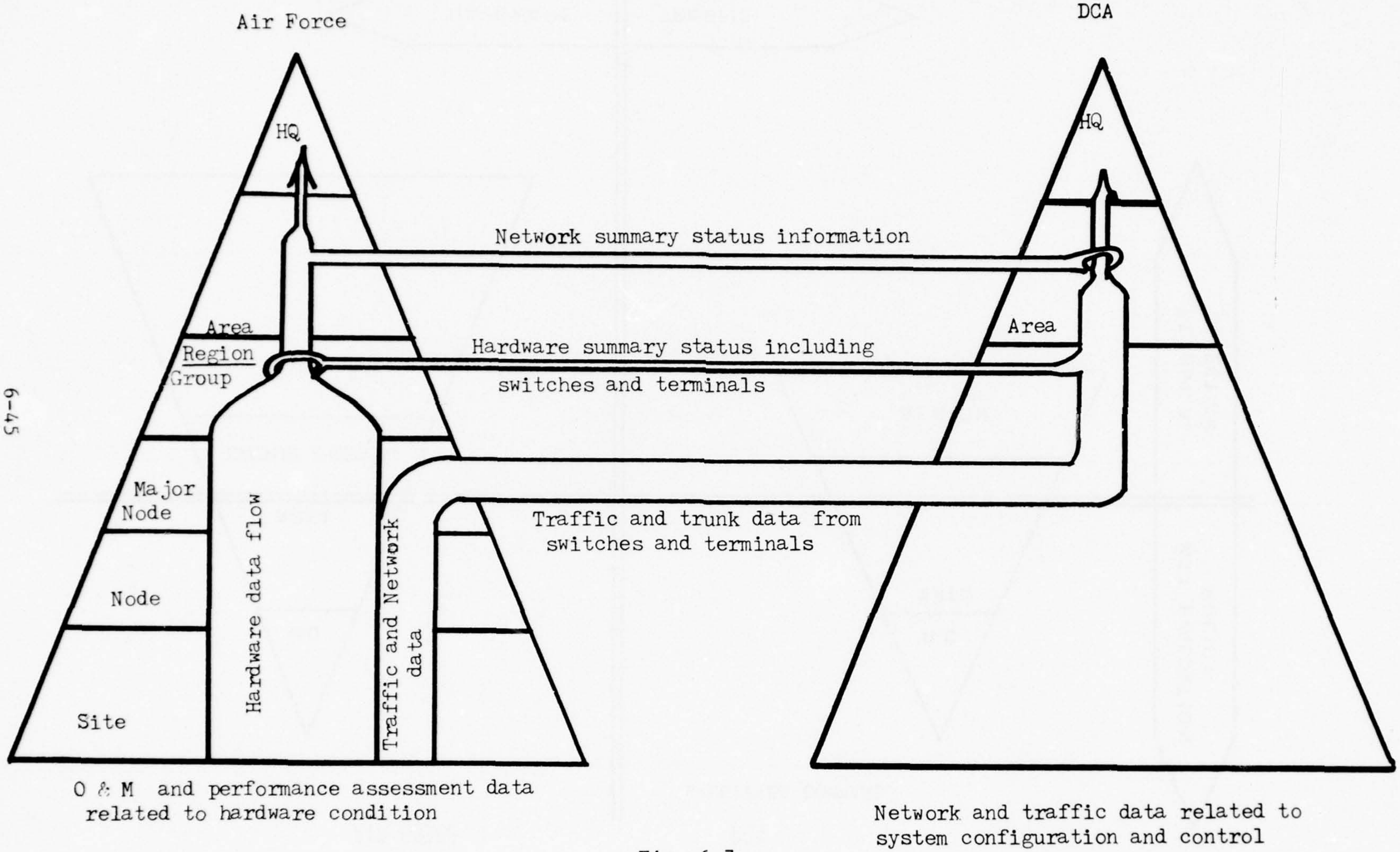


Fig. 6-7

SYSTEM RESPONSIBILITIES

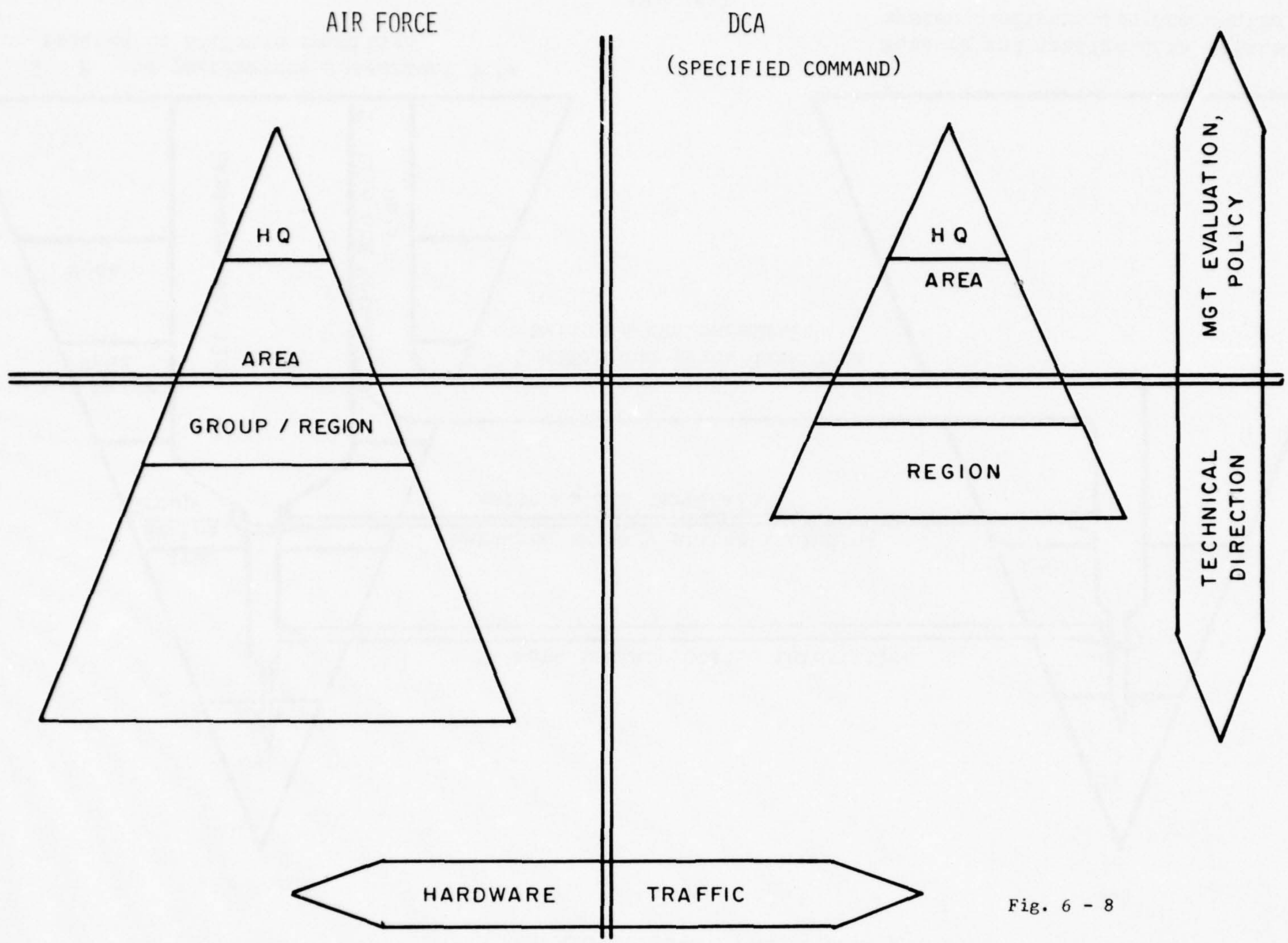


Fig. 6 - 8

several switches were involved, but the primary direction and control will undoubtedly come directly to the concerned switches from the DCA Area.

To keep the network control system both responsive and also robust in the face of hostile or adverse natural actions, many and perhaps most of the network corrective, protective, and survival actions will be preplanned. The switch sites will implement these actions as various traffic, trunk, terminal, or other criteria violates preset thresholds, but the switches must always be able to accept control direct from the DCA Area when required. Figures 6-8 summarize the overall division of responsibilities between the Air Force--an O&M Agency -- and DCA.

B. Analysis Impact

The operational impact of SYPAC will cause considerable change to the management approach now used by both the Air Force and the other O&M agencies, and also by DCA. SYPAC will sharpen the lines of demarcation between proper responsibilities of the O&M agencies and DCA, and will provide the appropriate data in adequate detail to permit effective fulfillment of both sets of tasks. The expression 'data adequate . . . to permit effective fulfillment' was carefully selected. Data, complete in every detail,does not 'assure effective fulfillment'. There are two major steps between data and a effective application of the appropriate action. The first, obviously, requires correct analysis of the data to provide a clear picture of the problem, of the framework of events or background around the problem, and to furnish a recommended course of action -- perhaps several for consideration -- to correct the difficulty.

The second step needs a responsive organizational structure between the decision level and the activities that must take the corrective action. This concept study highlights the issues and needed actions required to provide acceptable analysis of the SYPAC data. In a number of cases the corrective action will be a control signal sent to a box or device through the orderwire from the responsible agency.

1. Site

The analysis at the site is relatively limited, and under SYPAC a site includes the base cable plant and the base telephone switch. There will be built in or appliqued performance assessment devices on most of the hardware, monitor alarms and out of tolerance sensors to give unambiguous notification of the existence of a degradation and failure. The analysis to be performed at the site is primarily maintenance reaction to alarms and response to direction from Group. Since site personnel will be considerably less skilled than previously, the sophisticated analysis will be accomplished at the major node. The site personnel will only replace cards, switch devices, or insert new boxes and perform preventive maintenance.

2. Node

The Node has SYPAC hardware that brings together considerable data from the node radio, multiplex, power equipment, ancillary devices, and link data such as receive signal level, idle channel noise, etc. This data is assembled for not only the node itself and its links but from the other ends of these links. Further the node will have alarm, sensor, and

test and measurement results from the sites assigned to the node. There is much too much data for manual analysis, but fortunately most, if not all, of the routinely used information is amenable to automated reduction. Software in the computer can reduce the data. As the algorithms are developed, more data analysis can be automated. There will still be some combination of failure modes, intermitent conditions, or special and unusual situations that may still need some skilled human thought at the node or at the major node, for problem resolution.

3. Major Node

All major nodes have one of the major network switches colocated. The most common are Autovon and Autodin. Some special smaller switches requiring few trunks or having subscribers with small community of interest do not share this colocation criteria. Major nodes have much more data presented than a conventional node or site, because of all the inputs from the concerned network. In the past there has been little useful data presented from the switch to the major node, and there has been no meaningful attempt to tie together the backbone and network data. Obviously much of the major node backbone structure data can be processed in SYPAC automatically, since volume of data does not create a problem for a computer if the computer is properly sized. The correlation of switch data with major node data is still in the learning phases, but certainly will be heavily automated. Nevertheless, a few highly skilled technicians, NCO and officer, will be required to work on these classes of problems.

As will be discussed below, there will be trouble in identifying and

providing skilled system analysts -- for that is what they must be -- at all major nodes. The substitution of managers in lieu of switch site engineers deferred the development and training of this sophisticated competence. It is likely that these skilled systems personnel initially will have to be husbanded very closely and concentrated at fewer locations. Nevertheless, as soon as sufficient qualified people are available, the major node should have several.

4. Squadron

The Squadron, now considered a site, will have routine maintenance actions and PMI activities on the base telephone exchange switch and the mechanical checks that must be done on the old in place switches, but under the control of the Group. These exchanges are not likely to be replaced soon so must remain a personnel intensive activity.

The base cable plant can better be checked remotely by the SYPAC equipment at the node as part of the region responsibility. Thus the action to correct noisy or bad cable pairs can be directed by the node personnel and the base need have fewer and less skilled personnel.

The personnel on base who maintain terminals will generally remain at the present skill level. Presently they do little overall analysis and react mostly to customer complaints. In the SYPAC era, these terminal maintenance personnel will react to equipment self performance assessment, alarms, or sensors that point out degraded tolerances or major node or Group direction. Fewer of these people will be required, however, since there will be greatly reduced need for PMI or other routine tests to try

and find degrading boxes. Under SYPAC, deterioration will be assessed and only corrective action will be needed. The sheer number of devices requiring O&M attention at some major bases will probably suggest that one or two skilled technicians be assigned and they, by talent and desire, will do some manual analysis, but this does not change the principle. The base is not a communication analysis center.

5. Region/Group/Sector

The Region, the Group level in AFCS, is the technical key to successful communication system operation. The major node monitors too small an area and the operation of but one network switch. The Area is too high in the echelon of management to be able to handle all of the detail. Therefore, both by logic and by default, the Region/Group must assume the analytical lead. SYPAC supports this approach. The analysis will normally be co-located at a major node nearest the Region HQ buildings. This SYPAC element is provided additional memory and added computational capability. The memory will be used for recording all of the algorithms needed to reduce, collate, process, all the region network and backbone data inputs. The desired result is analyzed information with conclusions and providing as much in the way of a recommended action as possible. Much of the Group responsibilities relate directly to network or backbone hardware, and thus algorithms that fault isolate directly to a box or device that is degrading or causing problems, constitute a complete implicit recommend action -- replace or fix the device.

The Group/Region also gets status on the backbone structure from each of the major nodes in the region area. This data need not be in full

detail. Obviously, if most of the links are 'like new', there is no need and it constitutes wasted effort to process data when the answer is already known and is proper. Thus status information is all that is needed. This same status listing is also sent to DCA. Periodically a link or some other portion of the hardware assigned to the Group will degrade. If there is a spare device the report from the field element will identify the original faulty box, and will report that a spare already has or can be substituted. In this happy event, the analysis is trivial. In practice most major elements do not fail cleanly, they sag and degrade, normally over an extended period of time. Field elements do not react well to these sorts of long term chronic ailments. Thus much of the analytical power will be spent on examining data from past time periods, historical information, TEP test data, and original test and acceptance results. This previous status must be compared with current reports in order to detect these slowly developing chronic issues. It is likely that this area of attention will be both the most important and also the most tedious -- ideal for computers.

As experience is gained in the control of switched networks, the depth and breadth of the sensing can be expanded and the network thresholds and traffic conditions that indicate preset corrective actions are appropriate can be formalized and authorized to the Group/Sector by DCA.

It is quite clear that the software program at the Region/Group analysis and control location will be quite large. It should also be obvious that with a geographical region the size of England -- again for example -- all possible permutations of hardware, box, devices, radio and multiplex

equipment, antennas and wave guide conditions, terminal and switch operating state, subscriber load, etc., within the region, cannot be modeled for insertion in the SYPAC software program. Given this self evident fact, it follows easily that some manual capability to analyze unprogrammed situations is both necessary and practical. However, if the problem is quite unique, and if it happens infrequently, the technical calibre of individual needed will be high in order to sort out, from the alarm, sensor and routinely measured data, the general location of the difficulty and to derive the corrective action. Once the focus narrows, then special measurements by SYPAC can be made to complete the fault isolation. It must be constantly reiterated that in a communication structure, there never is a single difficulty even when one component completely fails, thus every routine and special measurement indicates some deviation from optimum. The analyst must be of experience and capability to note all of the deviations he finds, but not allow these measurements to confuse the search for the key problem, basic to a communication impairment.

It is not possible to point to any present class of technician or job specialty code as ideal for the SYPAC Region analysis task. The so-called analysts now scattered at many levels throughout the command are normally clerical or administrative people who tabulate numbers, and divide by N to give a simplistic average. 'In station handling time' or parts usage of a particular component are typical. Logistic and operational reports have a long record of absorbing fantastic numbers of man-hours, occupying

many manpower slots, producing vast reams of paper reports of little if any relevance or use. Yet many of the documents are reproduced in hundreds of copies, and are sent to many locations where they are dutifully filed or destroyed in most cases unread.

There is little possibility that personnel who have been long occupied in this 'turn the crank' thought-free operation can ever be trained or ever expected to do real analysis. The criteria for an effective analyst is not rank nor years assigned to the command. Neither is it a record of assignment to an existing analysis shop in AFCS or elsewhere in the academic or industrial world. So far those few people who have been successful at system analysis work have had 3 identifying criteria. All have had to some degree, all of the following:

1. Technical training -- This technical training may be engineering or science, or it may be a good technician school. (Keesler does not yet fit either category.) A few have achieved the necessary technical grasp in an avocation capacity such as a hobby. Note that an engineering degree does not assure analytical ability although the odds favor such a background.

2. Practical measurements and analysis experience -- The Scope Creek School or participation on TEP and Scope Creek-like teams is needed. Such practical training is required to insure an in-depth grasp of test measurement examination limitations and test results. Professors for example with only laboratory experience routinely have proved quite unable to analyze average routine field measurements results. Lack of practical experience has all but ruled out personnel untrained in the field.

3. Restiveness -- Those who have labored in a job for a long time without being classed as 'innovative' or a 'boat rocker' are entirely unsuited.

It is a sad but true fact that much of the communication system has been rather poorly operated. Many older personnel believe that all operational needs have normally been met. This is not the case. There are many services, unable to function fully, not the least of which is Autovon. This all pervasive voice network would not have been supported by the European backbone structure prior to TEP. High speed data services of 4800, 7200, and 9600 bits per second could not be instigated until the problems surfaced by TEP and subsequent special teams had been isolated, analyzed, and some of them corrected. The O&M agencies are still filled in many mid and higher level positions, both military and civilian, with complacent people who see no real need for technical education upgrade, basic philosophical change or disruption of simple already established procedures. Some of the new personnel assigned to units commanded by these uninspired people, are molded into equally passive personnel. Age, however, is not the key issue, although on occasions there is some correlation.

These three criteria may not be useful in programming the personnel computer, but No. 1 and 2 can and should be. Every precaution must be taken to remove those who do not produce after entry. This means that the OER cannot be prepared by technically obsolete or administrative personnel. It is from these mission analyst ranks that much of the new leadership of the command will come.

There was an organizational change directed by the command. This change moved all the TEP teams assigned centrally to the Area, and spread them evenly to the Region/Groups. It destroyed the only real in-depth mission analytical capability existing in the Area HQ. TEP teams cannot be kept deployed full time. They are used in-garrison for reduction of TEP data and special studies. It seems quite clear that TEP team personnel who normally fit two of the three above criteria and often the third, would be ideal for manning the analysis capability at the Region/Group. They have made all of the SYPAC measurements and they understand the constraints and limitations of such meter readings. They have learned to think in system terms and are not constrained by arbitrary staff division of tasks and so pursue real problems, unbounded by organizational lines. They are familiar with tech control operations and maintenance activities, and understand communication theory better than most. The TEP teams are ideal to form the heart of an effective SYPAC analysis and technical direction structure. Further, as the team members are promoted and leave the teams, they will be ideal to take over these higher Region levels of analysis and command. These personnel will be total communication mission managers, and should direct the NCMO technical activities.

Obviously, this analytical base for the region will be built over a period of time and in time phase with SYPAC. The emergence of unvarnished facts and an in-depth picture of the communication system will probably be salutory in breaking down some of the inertia at higher management levels. The source of adequate factual data also will be self motivating

to many people in the structure who now provide 8 to 5 passive participation.

6. Area

The analysis effort at the Area will be predominantly higher level mission accomplishment review. In the past this had to start from raw test data and actual measurements from the field. This made cohesive Area level analysis difficult and frequently impossible. SYPAC will provide already highly refined information to the Area. As the SYPAC hardware becomes more wide spread, it will be possible to automate much of the analysis and to present the data in form for easy staff digestion. These automated analyses will require about the same number of people as are now presently concerned with technical mission accomplishment, but this number is small. The number concerned with the routine and generally unproductive reports generation, however, is significant and could be cut with no mission impact and with a productive gain all through the command due to change of focus to basic mission issues.

7. HQ AFCS

SYPAC will present to the Area reduced data that will be processed there for use in rapid, but normally not real time corrective actions. Much of this same data, plus Area summarized information will be sent to the AFCS Hq. This data will provide the opportunity to observe day to day operations during emergencies or while making a study of some particular facet of mission operations. The SYPAC data can be sent by Autodin in off hours and accepted more or less directly by the HQ computers.

The type of analysis done by the HQ is clearly generic "to display the command status". This is a complex task and the NCMO will have to be completely restructured and the MIS completely re-done if they are to play any part at all.

The significant analysis of direct mission relevance presently is done in the Systems Analysis portion of Operations. This office has the bulk of the personnel who are able to grasp the impact of reported data. The NCMO will have to acquire some of these type people. The 'new' NCMO analysis products cannot be subject to 'coordination' by the staff as it is now. This coordination is synonymous with sterilization, and the basic facts, logic, and causes are either removed or generalized. There is some valid reason for the opposition to the present reading of uncoordinated field reports. Often they are in error and represented only a portion of true portrayal of the problem. SYPAC will both permit and force a change, and can result in factual and complete problem presentation. Manual and clerical processing of data cannot be afforded now or in the SYPAC era from a personnel standpoint.

The analytical efforts in the HQ after SYPAC are likely to remain as large as they are now in terms of people, but the character of the analysis will change. As mentioned earlier, the data can be processed at each level up through the Region in the SYPAC computer net. The data presented to the Area and HQ levels will be processed by large computers using separate programs. The type of presented data of course is dependent upon the desires of the commander and his staff. Some commanders state that they like to be current on field activities, so that they can

guide mission responsiveness. Other commanders state they want to focus on policy and leave the day to day running of the command to the subordinate elements. The truth is there can be no meaningful mission guidance issued, nor can there be any effective policy generated without a deep, and factual grasp of what the mission performance of the command really is. Thus regardless of the goals of the commander, SYPAC data and appropriate analysis must be a basic and mandatory foundation of any command posture. What the commander does after he understands the command posture is his decision. Action taken without a full understanding, however, is neither command nor management.

C. Software

There is an area of extreme importance not only to SYPAC but to every manager in every walk of life. The area is far more critical for a communication manager than a store operator, for example. This issue is software. A manager of a store of any type has available for his own use hundreds of already developed programs covering inventory control, planning, production control, and all the support activities such as personnel, payroll, etc. The head of a department store does not have to be able to understand all of the operations in order to qualify as a manager. He can use the predigested data fed to him by programs he or someone else selected. This instant program type of management helps explain why WT Grant and a number of other retail stores are now facing bankruptcy -- these managers did not really understand how their data was derived and processed and did not grasp the true meaning of the computer print outs -- they did not understand

the mission business.

In the communication system area, there has not been developed a battery of 'on the shelf' programs. In the first place, the present communication system has not yet really been managed as a total system. The Air Force made significant steps forward with the genesis of the Scope Creek type Commando Glow measurement programs in 1967. TEP and other measurement programs followed. These were characterization studies and were not directly usable by management -- in fact they were not much used by managers even after some analysis. The first major program to address system performance and intended for the use and enlightment of managers was the PMP. This daily performance assessment measures only the backbone structure, but it does this task well. The data is available to all of the echelons within the Air Force and DCA. Yet the average staff officer or commander has far from a full understanding of what the measurements mean even in a gross way. The Air Force has developed several software programs for correlating this link assessment data and presenting the results in graphic form. None of the software efforts have received anything like staff understanding let alone standardization among Air Force organizations so cannot yet be an 'off the shelf' program.

The procedures for performance assessment of switched networks are still in conceptual but partially demonstrated form as indicated earlier in this SYPAC study. There has been no Air Force or other service attempt to get agreement on what portions of the network parameter sensing are desired (or needed) by the various levels of management either in DCA or the O&M agencies.

The total interplay among the backbone structure and the network sensed parameters is not yet fully described. It is clear that the Air Force, the O&M agencies, and DCA do not yet have an agreed manner in which they desire to direct or control a communication system. SYPAC is a viable concept partially demonstrated in the field to permit formulation of such agreement and software development.

No one, however, can expect a full and complete software program for SYPAC until all the basic and prerequisite approaches are resolved and standardized within the Air Force and DCA.

There will need to be established on a formal and stable basis a highly competent group of people who are fully conversant with system management on a practical level, who understand networks terminals, switches, radios, links, hardware, etc., and measurement and performance assessment. These individuals must understand all elements. The capability cannot be formulated by men who know terminals, others who are good at switches, etc. This group will have to be the core of the system management definition and specification. A support activity of this quality group must be a programming agency like the AFCS CCPC activity at Tinker AFB. The present two or three people assigned at CCPC to ATEC is completely unrealistic. Industry assistance in formulation of principles basic management, performance assessment and control management philosophy will be expensive and quite likely only partially successful since few organizations except Bell has ever really tried to address a total communication system management task.

This blunt explanation is made, not to suggest that the SYPAC concept is not ready for operational implementation -- it is. Even with what is

known now, a great gain in performance; and an even more dramatic gain in savings in personnel at all levels, in data gathering, data formating, report preparation, report manipulation, etc. will result. An equally dramatic gain in saving of personnel in the analysis efforts will be forthcoming, as will be some savings in maintenance personnel and large logistic savings.

This management alert, however, must be made and made so clear that none can overlook it. There is still much work to do to define and implement an optimum system management approach, and before the maximum personnel savings are achieved. This is why a software/computer approach must be taken. Hardware approaches are cheapest -- if a complete definition of the problem was possible -- it is not. Firmware approaches are good if nearly full understanding of the present and future needs can be stated -- they cannot. Therefore, only a predominantly software based structure is technically, operationally and fiscally possible.

D. Hardware Impact

It is obvious that any time a serious attempt is to be made to restructure a large complex of hardware into a viable integrated structure capable of control, there will be problems that require both philosophical and practical changes in the manner of doing business. In the case of the DCS, the vintage of the hardware covers a span from recent manufacture to equipment 35 or more years old including well designed robust hardware but also incorporating some stop-gap articles of questionable design and poor

implementation. It is also obvious that some of the technical problems with the in place plant may be impossible to solve, or perhaps soluble only at an impossible cost.

There is a record of poor performance associated with certain contractors that extends over a number of years. Perhaps the procurement people have failed to hear the rumble of discontent from the personnel who have to live with these inferior boxes, or perhaps they feel nothing can be done. But for whatever reason, there is much hardware that performs poorly during most of its operational life, (though it may barely pass spec tests on the day of delivery). In the long run, this poor equipment costs 5 to 10 times as much as slightly more expensive equipment. This is easy to understand when recalling that the life time operating and maintaining cost is approximately 10 times the procurement cost for average quality equipment. If intelligent procurement of better quality hardware could reduce the O&M cost by only 10%, the initial cost could be doubled and still retain the same life cycle costs. In practice, a 10% to 15% price rise could get quality hardware and directly save more than 50% of the O&M cost. This means a net cost avoidance to the government of more than 5 times the original purchase price, and as a direct result, provide much higher quality communications during its life time. It seems strange that people who play the stock market and understand 'leverage', fail to grasp the tremendous leverage available on total costs by small increases in procurement costs.

Further, many items of hardware have a high cost of ownership. In-depth analysis normally discloses that some small portion of a large

assembly is the prime culprit. Selective replacement of only the troublesome elements is both cheaper and also long term more cost effective. When all tech order, training, etc. cost are included, product improvement is normally by far the best way to go. Certainly upgrades accomplished by simply substituting new equipment for old under the misapprehension that age of the hardware is the prime reason for poor performance rarely succeed. Age alone is never reason for complete replacement, although lack of logistic support is a legitimate cause for concern.

The small 'common' hardware, such as pads, amplifiers, SF units, echo suppressors, and many other devices used frequently throughout the DCS and the tactical world, are bought from the lowest bidder. There is little attempt at standardization to ease maintenance and reduce system logistic costs. Of even more importance there is little system recognition. As the communications services demanded continue to increase in speed, the marginally 'acceptable' devices become submarginal. For example, one amplifier bought in profusion highly distorts digital signals. In the case of voice, no one complained. When the same amplifier is placed in data service, the distortion introduced by one amplifier is approximately half of the total distortion expected from all the rest of the backbone structure and network hardware on a trans-European data circuit. In spite of the obvious trend to digitization, these amplifiers are still being procured and installed.

It should be noted that added capability, in SYPAC for assessment and in the applique for self assessment, exchange to a degree for equipment

quality and permit procurement of somewhat lower cost and quality hardware, based upon the SYPAC ability to catch the more rapid degradations prior to failure and operational impairment. SYPAC major implementation actions require study, standardization, procurement, installation, and management integration. While the individual actions are legion, several major areas of consideration are covered below, and encompass hardware, software, people who operate, maintain, and manage all facets of the system and the requisite communication orderwire structure.

Terminal Self Assessment and Control

As explained in the discussion on terminals there must be a DOD wide change. No longer can just any 'cheap' or inexpensive terminal be procured off the shelf. The development and production specs for military hardware and the procurement documents for commercial equipment all must have in addition to the normal performance specs, a strong and complete section, specifying the three key features: 1. built-in or appliques performance assessment concept to be employed; 2. manner of local assessment readout; 3. the standard self-assessment and control signals needed by SYPAC. The output can be either of the two general types as described earlier, that is, it may be sent down the mission circuit as a part of the normal signal or as an out-of-band or add on tone; or it may be sent to both tech control and to the net management on the net orderwire -- as determined by the basic network design or by the developers in conjunction with the DCS system engineers. There must also be the reciprocal path 'control' mechanism as part of the basic terminal design.

These features cannot be an option, they cannot be a feature that can be negotiated away to lower the initial procurement cost a few per cent and raise the cost of ownership and deny 'control' capability and cannot be deleted from the procurement documents because some manufacturer claims his device without these management features 'is just as good' or that his MTBF is such that his box 'will never fail'.

It is desirable obviously to select a limited few effective approaches for standardization by the DOD. If this were done, commercial industry might accept the same approach. If so, interoperability would be greatly eased, and the cost both to industry and to the government would be reduced considerably. While industry has insufficient need to justify the development costs, many commercial nets would undoubtedly use the fruits of military sponsored standards.

Provisions should be made to permit integration, consolidation, or combination of individual box self assessment and control signaling so that assemblies of boxes, routinely used together, can be assessed and controlled as an entity.

Special Sensors

Work done by AFCS in further defining the network assessment portion of SYPAC have disclosed the need for a monitoring function that can most efficiently be accomplished by special detectors. The discussion on networks, covered the non-interfering in-service performance assessment capability, demonstrated using ATEC. However, it is not efficient to watch for the momentary appearance or disappearance of events, using SYPAC

scanning sensors. The lowest system cost and highest cost effectiveness is certainly by 'camp-on' detectors of suitable design and small size. These detectors would be used routinely at all tech controls, all patch and test facilities, at terminals or other communication sites where important device complexes are installed. These special sensors must be conceived as part of the system and must be designed to meet specific classes of signal detection needs.

E. Orderwire

1. General

Most people who have worked in the field have viewed the orderwire structure as a minimal communication network to ease a few of the actions needed to fix boxes at a site or to resolve conflicts among several people trying to decide who "owns" the trouble. Unfortunately, that is how it has often been used.

SYPAC or any future automated control system will require an entirely new concept, and the orderwire structure needed to support these concept is much different. The orderwire must be viewed as a part of the command and control mechanism needed to effectively control the DCS. This mechanism includes the performance assessment fault isolation, data interchange aspects, and the requisite control structure to optimize the communication quality, to maximize the communication flexibility, and to minimize the personnel requirement in all phases of the maintenance and operation of the DCS. The orderwire cannot be considered as an isolated entity, a convenience or maintenance channel only slightly related to the communication system. The orderwire structure is related to the DCS

in much the same manner as the Command and Control networks are related to the operational fighting field organizations. The orderwire structure is the command and control portion of the DCS.

In the command and control world, this command network is used for:

a. Issuing orders for conduct of the operation, directing certain actions, and distributing planning data, etc;

b. Receiving status of forces, condition of facilities, and other resource data; and

c. Reporting results of operation, difficulties encountered, and requests for assistance.

In the communications world, the command and control network -- the orderwire structure -- is used for:

a. Issuing instructions on the manner of operation of the various networks or backbone structures, directing hardware reconfiguration and other network operational restructuring;

b. Receiving performance assessment status of hardware, reporting traffic status and conditions of message flow; and,

c. Reporting the stresses as a result of abnormal operations, the change in network or backbone status following a centrally directed change, and forwarding requests for assistance.

It is obvious that this parallelism must be true. Clearly the active command and control of the DCS is not exercised by the organizational chain threading down through the serial HQs. Equally unconcealed is the fact that the local site commanders, tech controllers, non-commissioned officers in

charge of maintenance or operations of the various portions of the network or backbone structure cannot all act in unison and in technical agreement to control the system.

Thus, the conclusion is inescapable: there must be an effective command and control structure organized and implemented for the military communications system.

The orderwire, as the command and control channel for the entire system, must be a well-engineered entity, designed as a subsystem of the backbone structure and an integral part of the networks, and these subsystems plus the control downward structure must form a coherent entity suitable for command and control of the total communications system.

No one who has ever conducted a TEP type backbone assessment or a Performance Assessment of any of the major networks can possibly be convinced that the DCS has even a marginal orderwire setup. The deplorably inadequate scope of the present orderwires is one of the most severe impediments to acceptable system performance.

Several years ago, during a vist to the Bell Telephone New York tech control, the subtle beauty of their control mechanisms emerged. For reasons well-understood by large advertisers, Bell had constant manual monitoring of all network TV channels at number of places across the nation. During most of my stay, the nationwide 'system' orderwire was quiet. Just once was it used. (This would be called inefficient by some personnel who would try to put mission traffic on the circuit.) A call came in "L.A. -- have lost TV number XX." The N.Y. tech controller -- really system controller -- quickly reacted and the conversation rapidly

moved to isolate the problem. Key major nodes were also connected in party line fashion to the orderwire so had already heard L.A. report. The N.Y controller did not have to evoke explanations or any introductory conversations. He merely spoke "Chicago." Chicago immediately responded "OK here." Thus the program from N.Y. was troubled in the western half of the nation. Omaha and Denver likewise responded that all was well. Salt Lake City responded that he too had lost the program. N.Y. directed Salt Lake and Denver to get on with fault isolation. These two major nodes immediately dropped off the system orderwire and performed a smaller version of the same type spot check to find the general problem location, using a 'major node to major node' orderwire structure. The first isolation to the Denver-Salt Lake section had taken about 15 seconds. The N.Y. controller then used the system orderwire to call up the major nodes required for the needed reroute. Again all the nodes needed were immediately available. The reroute required only a bit over a minute. Then all became quiet again. The system orderwire usage had been less than 2 minutes out of the hour of the visit, but it was effective. There was no tedious time consuming sequential dial up of the key nodes, there was no repetitive explanation to each site, there was no disruption of normal maintenance coordination and locally related tech control functions. The Salt Lake City and Denver controls managed the continuation of the fault isolation until it was located between two small controls. Then they too dropped off their major node to major node orderwire. The two small controls completed the isolation on the link orderwire. The most important observation must certainly be the rapidity of the actions. There was no waste of time, and time must

to the Air Force and the DCS be the key to command and control for national survival.

The commercial telephone company orderwires do not ride the mission channels. Thus the orderwire did not fail simultaneously with the mission network. The commercial carriers, even where the profit motivation is overriding, clearly recognize the necessity to be able to talk to all concerned sites or activities simultaneously, even in the face of complete path failure. They have established an orderwire structure needed to do the system job. They have not lost sight of the total system overview and control activity to save one or two communication channels. The DCS has evidenced the classic suboptimization approach and by saving the two orderwire channels have jeopardized the very survival of the communication system during emergencies of war or other calamitous events.

Fig. 6-9 is a simplified representation of the European backbone structure. Fig. 6-10 shows the needed levels of orderwire for the effective control of this backbone structure, geographically straightened for ease of portrayal. The highest level orderwire is the system. It is a full time party line with all major nodes connected. It is the command wire that permits instant alert of the entire structure to a problem. Any one of the major nodes can detect a difficulty and by a word galvanize the entire system to action. The system in the Bell example was triggered by the failure of a TV network. The system orderwire was next used to isolate the portion of the system that had failed down to the two major nodes straddling the difficulty so that the portion of the path needing altroute could be defined. Then the system orderwire was used to restore the services quickly.

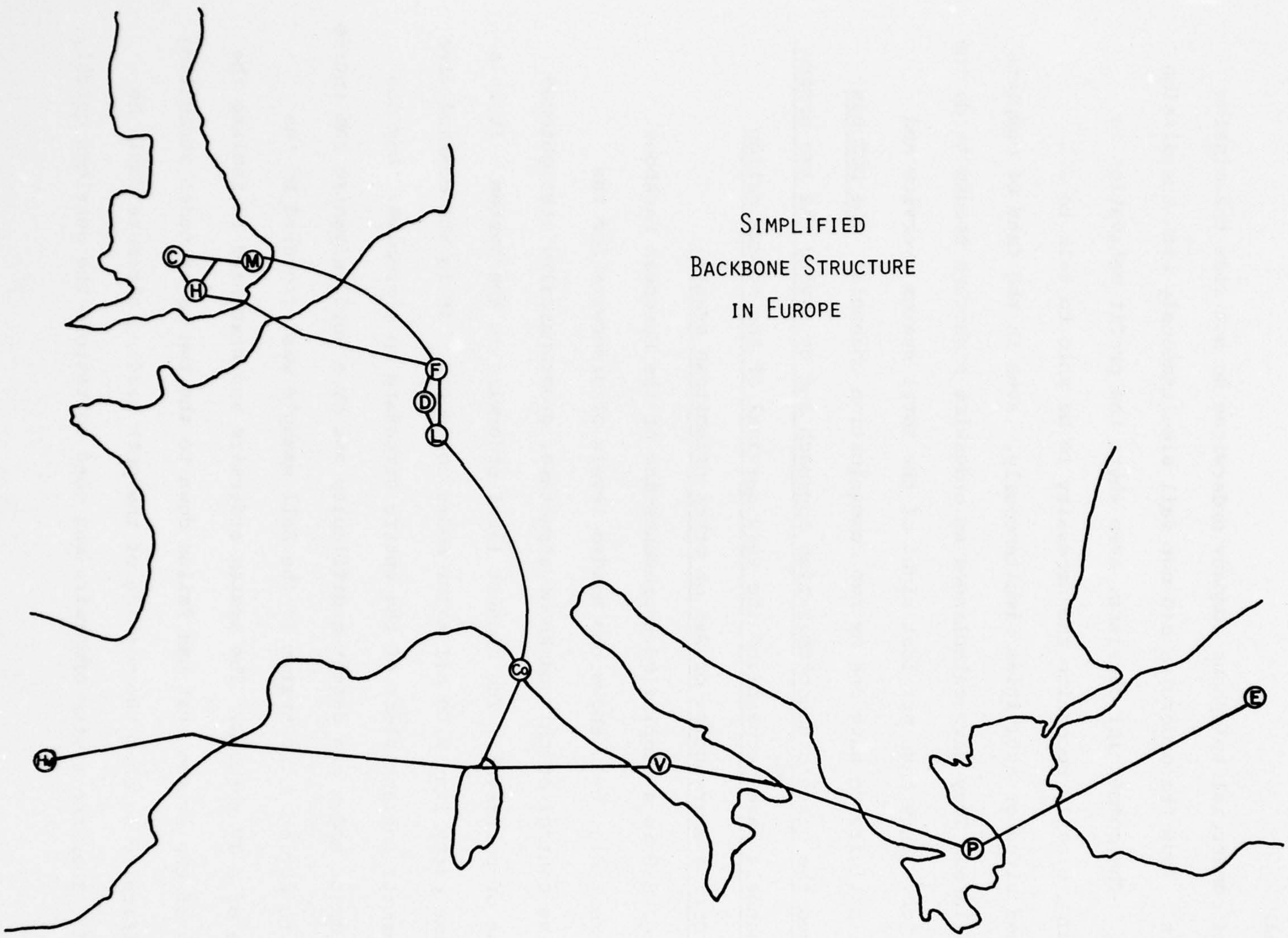
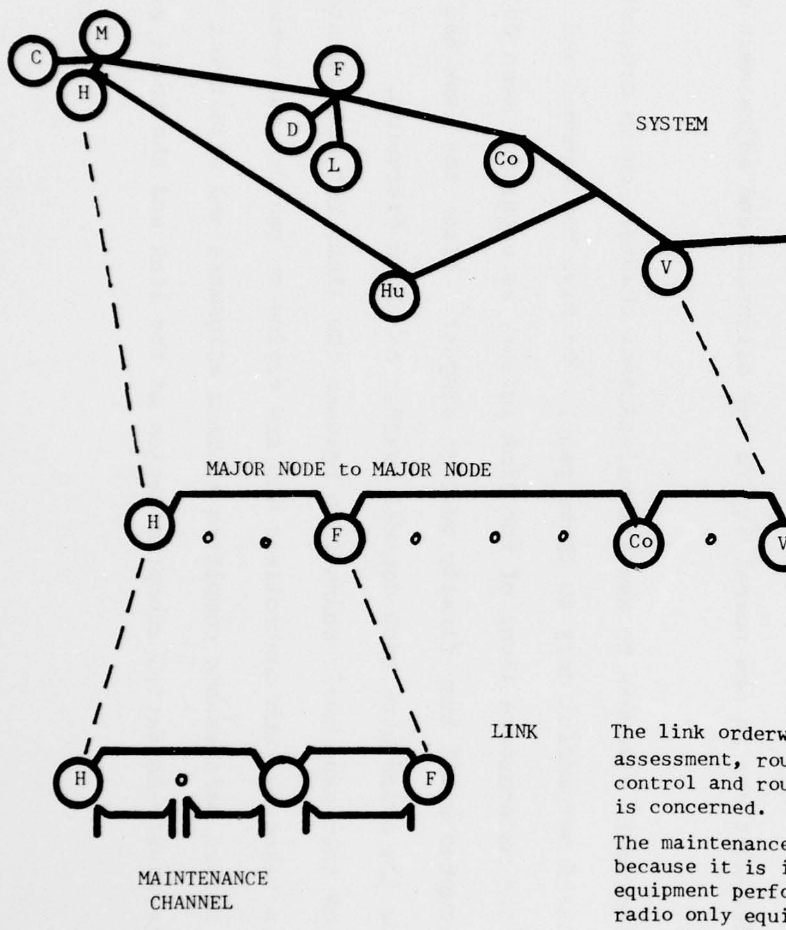


Fig. 6-9

REQUIRED ORDERWIRE STRUCTURE



The system order wire is the basic command and control network to isolate problems to a limited area, to issue major control instructions system wide, and to report major backbone and network difficulties. (predominantly voice)

The next eschelon command and control net to further isolate problems to troubled links or sites, to control corrective actions, and to regulate normal alignment activities and assure highest possible system reliability. (requires both voice and data)

LINK

The link orderwire is to control day to day performance assessment, routine link maintenance, hardware and resource control and routine fault isolation where no system impact is concerned. (requires both voice and data)

The maintenance channel is not terminated in tech control because it is intended to be used in day to day radio equipment performance assessment and repair relative to the radio only equipment at both ends of the link. This maintenance channel must appear even at repeater sites where there is no audio or baseband appearance. (solely voice)

Fig. 6-10

This same orderwire could not have been used for fault isolation without blocking the centrally directed action to altroute the failed path or channel. Thus the fault isolation between the two major nodes was conducted on a major node to major node orderwire. These major nodes have much backbone structure and network business to transact, thus the occupancy of this major node to major node orderwire was limited to the further isolation of the difficulty to a link. The further isolation to site or portion of a site was done on the link orderwire. Had it been a hardware failure on a site, the repair action could have been completed without further need for an orderwire. In the Bell case, the failure was of a link and coordination between two radio locations was required. This radio to radio communication was done on the maintenance channel. The maintenance channel is not an orderwire in the normal sense, but rather a maintenance contrivance. It is in very frequent use in the normal day to day alignment and adjustment of the link.

In the past, attempts to use the maintenance channel, as an orderwire have appeared successful only to those people who have not watched and measured the maintenance level of the link suffer, as repairmen were delayed and interrupted until they finally quit in disgust. After the link has failed and the order wire tech control traffic has been disrupted, maintenance then uses their channel to restore the link, but then maintenance channel is taken by tech controllers who are trying to restore the network services before maintenance completes minimum alignment and adjustment -- a completely self-defeating suboptimization of the link and the total system.

The above described commercial orderwire is not carried in the mission bandwidth of the traffic being controlled and protected. Rather it is carried on some paralleling broadband structure. This gives assurance that mission traffic cannot fail simultaneously with the control orderwire -- all of this to protect a soap opera.

In the DCS, however, the possibility to provide control orderwire channels on a separate paralleling backbone structure is highly constrained and in many geographical parts of the world is impossible. Fig. 6-9 System Orderwire shows few portions where a parallel route exists. There is, however, another approach that separates the orderwire and the mission traffic completely all along the route and in all hardware aspects except the actual radio link equipment. The solution is to put the command orderwires below the mission bandwidth in all FDM radios and in a separate bit stream for a TDM structure. There had been agreement to this approach in the early 1970's, among DCA and the services. This agreement stipulated four classes - the System, Major Node to Major Node, and link orderwires and it also included a local orderwire radiating starlike around certain tech controls. The maintenance channel for O&M use was mentioned and specifically excluded from the orderwire connotation. Thus a full orderwire structure would have 4 categories of orderwires plus a maintenance channel.

In 1975, DCA abrogated this agreement and specified a two channel orderwire structure consisting of the local and link circuits, including the maintenance channel. The two most important command and control orderwires, the System and Major Node to Major Node were to be provided

in the mission channels. Thus DCA has ignored the very basic rule that even commercial carriers follow -- separation of control and mission traffic.

There is an even stronger reason for pursuing this issue. The new digital backbone radios being considered are being designed with a mission data bit stream separate from the 'overhead' bit stream. The present design overhead stream is 192 KB. This is divided into 2 voice channels and one radio link alarm channel. Thus the DCS will provide only two orderwire channels one of which is the maintenance channel. The projected four orderwire structure is now down to one channel. This concept puts all orderwires of overall system relevance in mission bandwidth jeopardy. The blythe assumption that by some form of voice encoding DCA can use 16 or 32 KB vice 64 KB to derive 4 voice channels is not realistic or practicable. The number of decoding/recodings that can be accepted and conferencing problems reject this approach.

The difficulty with all discussions on orderwires is that to the personnel with field experience several years old or to the unskilled observer, the present two orderwire system seems adequate, and for repair after break activities it is in times of low stress. The point completely overlooked is that the two control channels are not even adequate now for the PMP. In times of communication stress the whole recovery approach is stalled. In times of real wartime hostilities, the command and control orderwire structure in place or planned for the digital structure will assure hopelessly slow reaction and can be expected to deny communications unnecessarily.

2. Backbone Structure

It is demanding and somewhat tedious work to keep a communication site at peak efficiency and nothing destroys the initiative, effectiveness, and capability to do the job more completely, than being prevented from doing the job because of the inability to talk to the people, all the people, concerned in the action. Teletype or other data terminal does not always suffice. SYPAC will be better, but cannot replace a voice contact on some problems.

One of the existing conventional orderwire schemes is considered by some to be ideal. It consists of a major node to major node long party line to which all stations are connected. When someone desires to talk, he dials a number and the appropriate phone rings. If he has to work with several, he must dial each in turn and then have them stand by while he dials the others.

There is one 10 site, multi-hop backbone structure called A through J for simplicity, implemented with this outlandish orderwire. The author has often observed the action and conduct of these orderwires.

Invariably A is talking to D, for example, consequently, as in all party lines, B,C,E,F,G,H,I, and J cannot use the structure and must wait. The controllers have become so disenchanted with the time, trouble, and harassment needed to complete even a relatively simple job, that they give up. Thus to an unskilled observer it appears that an orderwire is free. The truth is that if all the tech controllers were active and effectively attacking the system problems, the orderwire structure

unsuitability would be obvious to about everyone. This ineffectual approach was devised under the sub-optimization guise of saving overhead circuits, and providing more mission channels.

In practice a tech controller who really needs an orderwire circuit and cannot sit and wait, uses Autovon at "Immediate" precedence. This uses much more overhead, disrupts precedence calls, invalidates the pre-empt concept and in reality does not save orderwire circuits. Further, on all of the evaluations in Europe, by the author, an "Immediate" precedence call had a very high probability of pre-emption within any 3 to 4 minute period. Clearly, the orderwire 'piper' is being paid, but at a very high cost. SYPAC and the conversion to a digital structure will not affect this field necessity to accomplish the job one way or another, even if the HQ fails to provide adequate facilities. Any attempts to improve system control without full support to the communication system command and control orderwire structure is guaranteed to be less than cost effective.

3. Networks

In the past, some networks have had an orderwire. These orderwires were routinely among the switches in a switched net, or among the several important users in dedicated networks. On occasions switches or important users were connected to the adjacent tech control, but this was more a matter of interconnecting all colocated facilities than an attempt to interconnect sites having community of interest and common or supportive responsibilities. Further, only a limited number of people recognized that network functions must be coordinated and controlled if the total network was to provide acceptable service. Many people failed to recognize that the

networks were intimately and indivisably functions of the backbone structure.

Even the commercial telephone companies have special orderwire structures for network control. These orderwires, in the case of important networks, such as network TV, do not ride the mission channels. Thus the orderwire cannot fail simultaneously with the mission network. The commercial carriers, even with only profit motivation clearly recognize the overriding necessity to be able to talk to all concerned sites or activities simultaneously, even in the face of complete path failure. Thus, both the mission and orderwire connections cannot fail together. Bell directs and controls TV soap operas and entertainment programs more effectively than DOD manages for survival of the national communication system.

There are requirements for performance assessment measurements and interchange of data both with other concerned network locations and also with key involved major nodes of the backbone structure. There are also network requirements for hardware terminal assessment and control. The existing orderwires within the net has yet to account for switch hardware performance assessment and reporting.

Over and above the hardware aspects, there are operationally related traffic flow, queues, or other status situations affecting the network operation that need network orderwire capacity to gather.

There are as yet no full communications provisions for reporting in real time to a network or central control site for decisions related directly to hardware allocation, switch control actions, or traffic matters. There are no orderwires for exercising real time control of any total integrated

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sort. In fact, the network hardware presently could not accept much remote or local control if it were offered.

There are few DOD people who really grasp these true network orderwire needs including the author. Perhaps that is to be expected since neither the Air Force nor DCA has ever attempted to really manage a network or system. It should be clear, however, that the network management task is at least comparable in complexity and sheer data bulk to that of backbone structure management. The network control portion clearly is more demanding from a data quantity viewpoint and all of this impacts the orderwire size.

4. Overhead

The orderwire structure above has been addressed as it pertains to the backbone structure and to the networks. There is also a need for the creation of a viable overhead network.

In any automated reporting system, however, much of the data acquisition, processing, and forwarding is done by inter-connected computers. It seems clear that it will be most economical, at all lower levels and probably up through to relatively large geographical area HQ's, to use the same orderwire nets to sense, gather, interchange, and report data. Once this data processing hierarchy is established, little is to be gained by breaking out other reporting or interchange requirements from the basic orderwire net and re-entering in Autodin or other mission channels.

The only exceptions would seem to be those reports related to summarize historical data, trend past performance, or tabulate data needed for planning and managing a world wide system. Likely, AFCS or DCA HQ reports would probably be the output of summarized and reduced data at an area HQ and

so would be removed from the orderwire network.

5. Control

The orderwire network to date has never been required to provide command and control to the DCS system. The DCS must create such a control function if any realistic national emergency survival capability is to be created. There is also a considerable responsiveness and performance gain to be achieved by such control during alerts or natural stresses, and some quality and flexibility increase during normal operation.

It is theoretically possible to issue all control instructions from one central HQ in the CONUS, but the tenuous nature of a communication net from all over the world, the vast quantity of data needed, and the computer/software size and complexity, clearly mediate against such an approach. Policy guidance will have to be exercised from one point, but the bulk of the control must be geographical, Area or lower. Thus, the orderwire demands for control are concentrated in the Areas.

The orderwire size to handle the Area HQ downward system control signals need not be large and will certainly be a small portion of the input/report rate.

If for no other reason, there is one compelling issue to cause the establishment of an efficient separate orderwire structure, addressing the several separate networks, and a backbone configuration. In case of complete failure or destruction of one or more links or a switch site, the orderwire structure in its entirety can be returned to service quickly so that all networks, dedicated channels, and the backbone structure restoral actions can progress in parallel. The present party line approach will

absolutely assure that the bulk of the restoral actions will be sequential. The networks, the real reason for the communication system in the first place, clearly will not be the first to be restored, since the network personnel cannot even talk until the backbone maintainers have repaired the out-of-service link and any related Autovon structure.

It seems likely that the equivalent of 4 full voice channels, if the data framework can be designed, formated, and operated in a 2 or 3 network configuration, would be adequate, and would release numerous mission channel now used as reporting circuits, alert channels otherwise not available for general usage. The SYPAC automated data interchange laterally as well as vertically probably can be a voice plus data approach. All these orderwire channels are going to have to be provided in some form, either out of band or by dedicated circuits in the mission bandwidth. In either case the loss of bandwidth will be equal and in practice probably much greater in the present undesigned, makeshift approach, and still the mission bandwidth and the control orderwires fail together. Further in the digital world the 192 KB constraint will be expensive and probably impossible to change downstream, when the SYPAC enters operational use.

The opposition to providing an adequate command orderwire structure is really specious. If in any locations, the full four channel compliment or orderwires were honestly not required, they could be used for mission channels so no bandwidth would be lost. <u>Thus there is literally nothing to lose by doing it correctly and there is much to gamble by the present DCA approach</u>.

The author believes that the 4 orderwire plus one maintenance channel can suffice not only for the backbone structure, but also handle most and probably all the network functions and system control. This assumes that the in-band terminal/assembly orderwire concept is implemented as discussed elsewhere in this report.

F. Line Conditioning Observations

Since line conditioning proved to be so troublesome not only in Europe but during numerous other field evaluations, a series of special field tests was conducted. The ATEC design makes the test simple to accommodate and permits a whole new approach to line conditioning. Although there is no scientific reason, line conditioners are normally put at the receive terminals. Technicians place a test instrument at each end and they measure the amplitude and phase distortion. Each subsequently adjusts a line conditioner to the appropriate settings. Thus, for a two-way circuit, two line conditioners are required, one at each receive end of the line.

There is no reason for this receive end convention except ease of conditioning a line using manual test equipment. This means that much conditioning equipment is located in sites often well away from centers of maintenance and tech controller expertise. The basic concept is wasteful of manpower, costly in time, inconvenient from an access standpoint, and as demonstrated in the field, does not work well. ATEC has a built in logic for line conditioning that is unique and can be a highly valuable asset. ATEC also has the capability to automatically and quickly make line

conditioning tests not only with another ATEC, but also with conventional manual test equipment.

ATEC takes the line measurements from the receive end to the ATEC. The line next is looped at the remote point and an ATEC loopback line conditioning test rerun. ATEC will then automatically calculate the unmeasured ATEC to receive point path. This ability to measure from B to A, and from A to A through B, and then to calculate the B to A direction makes it possible and easy to save half of the presently done measuring. Further it cuts the need for skilled technicians since the man at the remote site need know nothing about line testing. He need only be able to follow the knob by knob instructions from the ATEC operator. This was demonstrated with a newly arrived 3 level at a remote site. All measurements were completed, with nothing but manual connection and knob twisting by the untrained operator.

A highly useful system capability can also be obtained because a line conditioner can be installed anywhere between the transmitter and the receiver. The line acts like a filter, the line conditioner acts like the reciprocal filter, so that the resulting composite overall response is linear. Picture a 'U' shape open end up in series with a 'U' shape open end down with the bases touching. The sum of all points should be straight horizontal line. One U represents the line, the other the filter. It is clear that it is of no consequence which 'U' precedes which. In most cases, the conditioner located at the center of the line may be slightly preferable to either end. In all cases for standard modems conditioning anywhere in

the circuit is quite acceptable. In fact, on one test an equalizer adjusted to condition the total circuit length was placed in England, and pre-equalized a circuit looped back to England from southern Italy. The performance was equal to any other configuration of equalizers.

Given this pre-equalization acceptability, ATEC instrumented tech controls will be able to conduct one-way or loopback measurements and record or calculate the line equalization parameters and store them in computer memory. The ATEC instrument will then provide the capability to adjust an equalizer in station, for installation at that the ATEC tech control site. The equalizer need not be installed to some remote site. Management can decide where support is most easily provided.

It obviously would be beneficial if all equalizers were placed at one or a few of locations near the ATEC machine for '20 second' checking periodically.

SYPAC obviously will incorporate this capability. In the hybrid digital world the centralized conditioning facility will be at the analog/digital interface.

VII. SYPAC IN CONUS

A. Introduction

Most of the SYPAC study has been described as it pertains to the overseas DCS. There the backbone structure and the networks are generally U.S. government provided and operated and maintained by the three U.S. military services. The operational control of the overall system is clearly the responsibility of the DCA system manager, If the system does not meet the operational need, the decision to overbuild, replace, or to improve operation or maintenance clearly belong to the system manager. This overseas singular system accountability is both the best and the clearest possible situation. It is unambiguous because if the DCS fails to meet the need, there is clearly one agency responsible.

1. Conus

The communication problem in the continental United States and in a few selected locations overseas does not fill this single manager pattern.

In the conus, it is government policy to install only those facilities that are not commercially available. In the U.S. that means that none of the major backbone structure is government provided. Bell and Western Union have wide flung structures for their own use, and the DOD leases circuitry as required. Bell provides the bulk of the needed connective structure, with Western Union and more recently Commercial Satellite Corporation and the new limited service digital companies furnishing the balance. The government may provide the base cable plant or that too may be leased. The data or other terminals used in the Conus may be government owned or leased. There are

bases where only the subscriber is government furnished. Attempting to manage a DOD communication structure where most of the resources are not DOD controlled is obviously a far different problem than that facing the overseas managers. The recent decisions by the FCC, that permit and, in fact,encourage competition with Bell, yet force Bell to furnish the tail connections within the cities, has in one action made the previous management problems grow by many orders of magnitude.

Even before the proliferation of transmission media companies providing long distance circuitry, the management was very difficult. For example, a subscriber in Washington, D.C., might have communications signals that traverse a terminal leased from Company C, travel through the Bell system, enter another telephone company structure, and then enter a base that is government furnished and then terminate on a company D terminal. This means that there are five major participants. If all works 'well' -- meaning that data can be passed with an error rate that does not cause the subscriber to complain -- no manager worries. But if there is an excessive error rate, or the terminals fail to synchronize, or otherwise declines to provide acceptable service, the customer complains. Who is to blame? Who has to take corrective action? Who leads the fault isolation? The fault can be the subscriber, -- he may be incorrectly operating his terminal. It may be the Bell portion, the other common carrier, or the base cable plant. It may not be just one fault. Practice proves invariably that there is never a <u>single</u> degradation. The terminals are each a bit deteriorated, the base cable plants at both ends contribute noise, and both common carriers add at least their fair share of noise. Who is at

fault? Where noise is the cause of the problem, noise could be removed from any one of the elements and the terminals may return to acceptable operation. Remember 3 to 4 db in a data interconnection is the difference from nearly error free operation to no operation at all. Thus each segment manager can blame another portion. Each could point to himself but rarely does so!

In the past, and even in the future where voice traffic is considered, rapid fault isolation is not always a requirement. During the trouble, the user can shout or perhaps redial the call and with luck it may miss the troubled portion of the connection. The subscriber rarely complains until a number of redial attempts fail. Much of the system could be inoperative on a quiet communications day and still have few if any customer complaints.

In this era of ever increasing data processing for personnel, pay, logistics, operations, administration, secure voice, etc., it is clear that much of the traffic moving through the DOD networks is digital and the failure mode is abrupt. With the government leasing and competition ground rules stated above, fault isolation is never fast, and in the future as the circuits traverse even more common carriers, the time response will get slower and fault isolation more acrimonious.

Presently, the DOD leases several alternate paths with as few common elements as possible in the hope that trouble will not appear on both routes at the same time. The dual routing technique is only affordable on high priority critical command and control lines. The rest of the networks must suffer delays, degraded serice, or outages.

2. Overseas

As mentioned earlier, there are a few locations overseas where the situation is much like the conus position. For example, there are a number of so-called gateway stations where the overseas DCS is interconnected to the overseas common carriers. This connection is always through the local Public Telephone and Telegraph (PT&T). This is always foreign government operated. U.S. is the only major nation where the vital communication nerves of the country are in private and commercial hands -- and so far it has proved better. Certainly nothing remotely approximating Bell System effectiveness is observed overseas. The problems of fault isolation in these PT&T's is more lengthy and difficult. Getting an initial circuit brought into service is a major administrative and time consuming episode.

All DOD services, with a few exceptions, that start in the Conus, traverse the fragmented paths described in the portion above, then enter the structure of the overseas carriers, traverse the PT&T structure overseas, before reappearing in DOD facilities. The last Conus and the first overseas DOD facility where these services appear is a gateway station, basically a tech control with only circuit responsibility. There are some gateway stations that are hybrid. Croughton, England, for example, is a full gateway station interfacing the DCS with the British communication system, and it also is a major node in the DCS. Andrews AFB, Maryland, and McClellan AFB, California, are two examples of conus gateway tech controls with no backbone structure assigned, although both stations have several local microwave links terminated.

Gateway stations are responsible for operational services, yet they control only the tech control interconnection portion. Presently their job is nearly impossible, and normally the responsiveness of personnel in these facilities is poor. These personnel have learned from bitter frustrating experience that with the facilities at their disposal, they have very little effect on the system. They quickly become reactive to troubles and customer complaints, and re-route or patch around troubles. They perform little fault isolation or system optimization because they have no control and little influence.

The DOD is not likely soon to get meaningful reports from commercial companies related to the service they are providing. Bell has a fair grasp of the performance of their major links in the backbone structure. The other commercial carriers have less awareness. The newest companies make little attempt at performance assessment, but rather restore the service <u>after</u> it has quit. As described earlier, commercial companies only strive for the goal of 95% probability of services. They do not even aim for 100% reliability. Thus the DOD cannot expect to meet their service reliability goals in the Conus.

This then is the problem. What can SYPAC do to influence and improve this clearly poor situation?

B. SYPAC at a Gateway Station

The tasks for SYPAC at a gateway station clearly are quite bounded presently when contrasted with those required overseas, although the general functions are still predominantly performance assessment, and fault isolation. Since the backbone structure is clearly assigned to someone else, the Air Force

cannot manage, in a real time sense, this portion of the system. The management, if that is an appropriate word, is applied after repeated failures, inept response in fix or restore actions, and inadequate reasons for outage reports. The 'management' action is to re-lease the circuit from someone else. The cause and effect are so far separated in time that DOD does not benefit greatly from such a generalized punishment approach. Frequently, there is no one else in a geographical position to provide the service, so even the pretext of management is lost. The more general use of satellites may give a bit more substance to this procurement approach, but even with satellites the tail portions still remain the same and so constrain if not prevent effective alternatives. Even though the backbone structure is not amenable to control it still can be performance assessed to a reasonable degree by any wide spread user such as the DOD. This will be expanded later in this section.

The other major portion of the communication system is the network. Even though many of the terminals are leased, they are located in Air Force facilities. The self-performance assessment read outs are available to that facility and may be made available to the tech controls or patch and test facilities along the path between the terminals. The switches in the two major networks are not operated or maintained by DOD personnel. Autovon is operated and maintained predominantly by Bell, although several other phone companies also are involved. Autodin is operated and maintained in the states by Western Union. In only a few command and control nets are the switches operated by DOD people who can provide status data.

So network management must be more subtle and indirect. Thus, the gateway tech control clearly has a highly constrained set of input data sources, has an unwieldy backbone structure, see Fig. 7-1, fractionated responsibilities, is cursed with rapid personnel turnover and has the highest concentration of important circuits anywhere in the system. Nevertheless, the tech controls and network managers must make, or force others to make, the networks play properly.

The basic concept of SYPAC as applied to gateway stations, accepts the facts that other people and other agencies must accomplish the corrective maintenance actions and hardware repair, and that they will be generally slow or unresponsive. Therefore, SYPAC must accomplish all the circuit performance assessment possible and alert the carriers as soon as possible after deteriorations appear. This will not make the common carriers move more rapidly, but it will give the carriers more time for corrective actions and may permit corrective actions prior to actual loss of DOD customer service. This is going to be a difficult concept to sell at first to the common carriers. Most commercial technicians and many service personnel do not like to hunt for a problem while the service is still acceptable to the subscriber even though it is degrading. The repair approach is to fix one box and then try the network. If it now works the trouble is 'solved'. If it does not yet play, then another box is fixed. There is rarely, if ever, a true optimization applied end to end so that all equipment is proper. The stressed self performance assessment concept described earlier in this report will give the new SYPAC approach much

support. Before outages are encountered the stressed threshold indicator will be flashing or otherwise indicating troubles. Thus technicians will be able to fix a box at a time, just as before, but now not to restore service, rather to put out the stressed assessment indicator and thus restore the full performance margin. Meanwhile the customer service remains at least acceptable. Most inertia can be bypassed by this approach. The occurance of customer outages will be classed as 'Red', while the indication or flashing of the stressed performance meter will be classed as 'Amber'. The military and much of industry is conditioned to respond correctly to these two color coded categories.

SYPAC as installed in gateway stations will set thresholds using many of the same parameters measurements that are used overseas. These include:

1. Signal level
2. Signal to noise
3. Unique signaling formats, that discloses operating conditions
4. Peak to Average ratio
5. Phase jitter
6. Signal signature and degradation analysis of spectrum
7. Measurement of selected tones or unique signals features

As will be noted, these parameters are the same ones used in assessing the performance of terminals, and networks overseas while 'in service'. 'Out of service' tests, or course, are identical.

Since the direct measurement of the backbone structure is denied, the

SYPAC approach will have to be indirect and the conditions inferred. There is nothing however to stop the direct measurement of those network signals, signal parameters, and unique features that describe network behavior as portrayed in Fig. 7-1. The section on terminals and network assessment described the approach.

It is quite simple and reliable for SYPAC to use the network signals to decide that something is not proper. This is the first step in any management activity to determine the question --'Is there a problem?' The second step is 'Where is the problem?' -- and this operation may be quite possible even for a base or gateway station. The self performance assessment capability, the loop back box , and the adjustable stress capability can prove conclusively that the problem is or is not within the terminal, or the base facilities. By elimination the problem can be isolated. In the overseas case, the fault isolation is to the specific hardware at a site or to a link or terminal of the backbone structure. In the Conus this isolation may only be to a contractor who provides the service where the trouble appears. This may be the backbone structure, the base cable plant, or terminal. The further fault isolation will be the contractors problem, but SYPAC can monitor the corrective actions and time correlate his approach. If there ever are contractors offering alternate services, this time documented record can be used to make substantiated decisions and verifying that after a change, whether the performance has improved.

C. SYPAC in Conus

The statement was made earlier, that gateway tech controls cannot

TYPICAL MILITARY COMMUNICATION CONNECTION

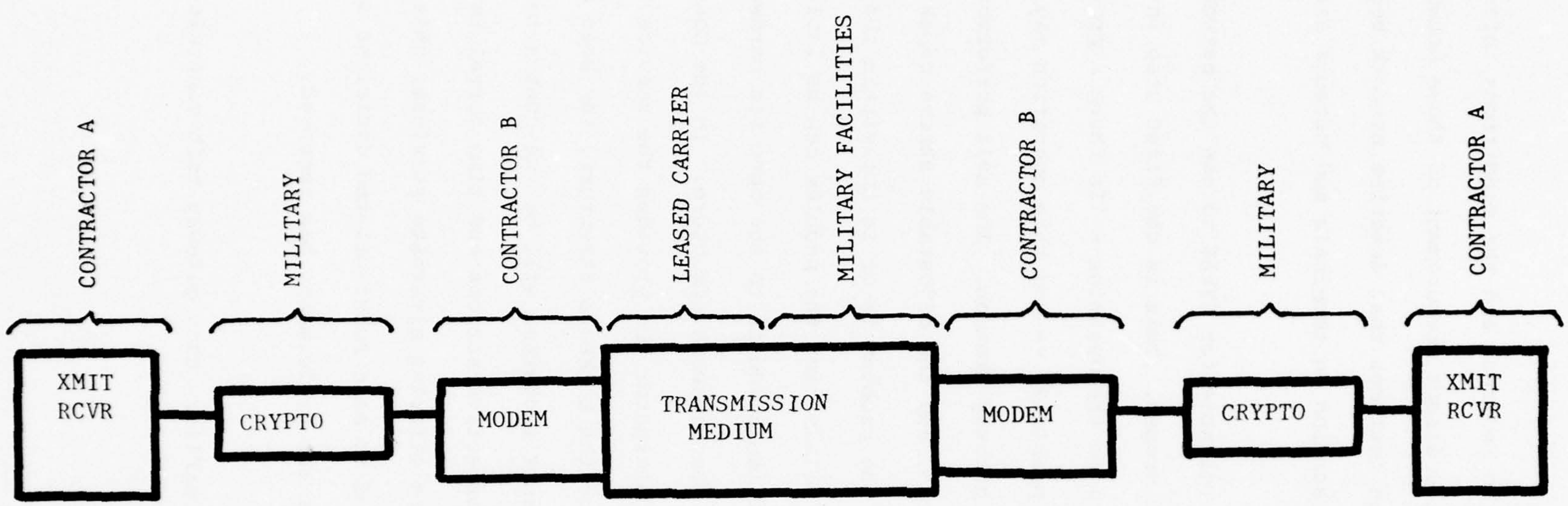


Fig. 7-1

performance assess the commercial backbone structure. This is true in the context of the class of backbone management capability exercised in the overseas areas. However, in a more general way, in the sense of seeing whether the backbone structure is being managed, it can be done. The telephone companies are not happy with the approach but there is no legal impediment, and no technical problem to measuring the circuit parameters on base, at the telephone as a last resort if necessary. Signal level, noise level, phase jitter, impulse voice, or any other voice channel measurement can be made at these interfaces. It is not practical to make these measurements at each telephone, but a central monitoring facility at gateway stations can work with major nodes/gateway stations overseas to monitor the condition and trend of circuit performance parameters. The gateway stations can also conduct measurements with the various communication concentrations in the states -- normally these would be located on bases. The history of circuit performance, the status of present capability and the trend all can be acquired.

Such a general assessment of a portion of the leased backbone structure is presently being accomplished in a limited sense as part of an ongoing assessment for the Autosevocom network. The Autosevocom tests are conducted from a central location, where a DOD secure voice exchange is located. Test calls are sequentially made to selected subscribers homed off the exchange. Test calls are also made to the other major exchanges throughout the network. At the present time the focus of the test calls is related primarily to terminal alignment. Only if the calls fail to go into synchrony

or other major problem is encountered is a line problem surfaced, and even then, lttle precise information is gathered on the line parameters. The measurements are made manually and do not include all the necessary and requisite parameters. The analysis is marginal, but the principle is proved. When SYPAC equipment is available, the full complement of tests can be made, quickly with automated analysis.

It is not difficult to visualize making measurements reciprocally between and among a number of major Air Force command HQ locations, special importance locations, such as test ranges, key operational bases, and important locations such as the Denver pay center. If management displayed the test results on a map, a fair picture could emerge showing where troubled areas in the leased structure were causing DOD network problems. On the dedicated nets, the concept is already proved. Further, the data, so derived, is a powerful tool for negotiating for improved service from the leasing contractors. There is even the chance that these common carriers might attempt to performance assess their own structure. This may have to be a forced function by the DOD. However, since the competition authorized by the FCC is already forcing less quality control in an attempt to save money and reduce the cost to the consumer, with the result 'cheaper', poorer quality service is likely.

Already, at one gateway station to Europe, this network evaluation technique already has worked. The overseas carrier had poor performance, but he denied it over a period of months. The gateway station made chart recordings on appropriate noise, signal and other degraded parameters. In a meeting with the VP of Operations, the young engineer, who had made the

recordings, proved his contentions. The overseas VP took corrective action.

Where the Air Force owns the base telephone plant, a central patch and test facility is an obvious and appropriate place to install SYPAC. Where the base plant is leased, it will be more difficult unless Air Force personnel can use the central office. But failing that, a SYPAC can still be installed and made to observe critical circuit and network parameters on selected lines. Obviously, bases are going to have to insist upon access to the mainframe for SYPAC bridged, non-interfering measurements to speed and ease the system management problem.

SYPAC can also be used to monitor and performance assess those circuits and networks in service that are used primarily or exclusively on base, such as control and voice circuits for Air Traffic Control and Navigation Aid, the network used between computers, between computers and their remote terminals, etc.

Thus, SYPAC cannot give the same system portrayal that it does overseas, and the correlation of network problems with the backbone structure inputs will not be available in real time, but anticipation of many network difficulties will still be possible.

VIII. SYPAC DIGITAL CONSIDERATIONS

System Performance Assessment and Control in principle is the same without regard to the type of system. Everyone who has taken courses on Controls knows the simple block diagram that portrays a closed loop-control mechanism. The basic block diagram elements do not change no matter what device is controlled. The important point to be made is that there must always be devices to sense the condition to be controlled. Assuming that the sensors and the associated feedback loop including the controller are not a limiting factor in speed or bandwidth, the controller in principle can control any system. That is, an aircraft autopilot can control not only an airplane in flight, but could also be used for control of any machinery where angular displacements are to be stabilized.

There is an exact parallelism in the case of SYPAC. The basic heart of the control structure is a digital computer. Its speed and capability is far more than is needed for the control of a structure as relatively slow changing as a communication system. There can be rapid failures in a communication system when a radio transmitter fails, or when a power supply blows a fuse, but the corrective actions in these cases are normally built into the equipment itself by some form of automatic switch over, or may be by substitution of hardware by remote control or by selection of other appropriate action by maintenance men after fault isolation. But these are not control actions in the normal sense.

In the aircraft autopilot example, the computer and readout mechanism

were designed to match and integrate with the gyroscopes that serve as input signal sensors. The autopilot computer and readout servo mechanism can match any number of other input sensors with maximum speeds equal to or slower than the original ones. The controller could be used to stabilize a submarine, a very similar application, or equally well control the movement of the bed of a large metal shaper. There is nothing to prevent the computer of the controller from being used to control the electronic functions of an electronic device such as a radar, perhaps given standard teletype input and output terminals it could be used as a small general or special purpose computer.

There are two specific examples of such cross use. One small computer was designed as a component of a missile stabilization, guidance and control subsystem. This computer, still mounted in the missile nose structure because of its unique packaging, was placed in an R&D lab, and used with a teletypewriter and a printer as a PDP-11 equivalent, and in fact was better in some aspects. In the other specific case, the computer had been designed and militarized for rugged use. It was applied to guidance of a well known Army ground-to-air missile. It was also used as the brain in an aircraft landing control and tracking radar, and as a small general purpose tactical computer.

A similar condition pertains in the case of the computer that forms the heart of the ATEC control mechanism. It was originally conceived and produced as a ruggedized computer for control of digitally controlled machine tools, such as automatic drill presses, or milling machines. In each case

the position of the drill head, or the mill cutters was sensed digitally and provided to the computer. The computer by software, guided the drill or mill through the proper sequence of drilling or cutting operations. The key of course is the sensors that detect the drill position in three axis to whatever precision is desired. The ATEC computer is widespread through industry in this application. The ATEC computer was reprogrammed to provide communication measurement and control. The computer now does not receive direct digital inputs as it did in its first application. Rather, the DC and AC electrical signals are digitized prior to acceptance by the computer. Most people refer to the communications signals traversing the tech controls of the Air Force as analog. By this they mean a special class of signals unique to FDM-FM structures. While the statement is true, it has an erroneous implication. To illustrate this point consider that the 60 cycle power that appears in every home is 60 cycles but it is also analog. No one refers to the analog house power as though it were a special class of signal. It is just A.C. 60 cycle power. When one has a flashlight the battery power is also analog, meaning continuous, but everyone refers to this as DC power. All of the signals that appear in tech control are either AC or DC. Some of the signals are discontinuous AC, some are discontinuous DC, and so are not really analog except within certain time frames.

DC signals can be measured two ways. The standard meter movement gives a convenient reading, or the stable voltage can be digitized and read on a digital volt meter. AC signals can be read on a standard meter also, but meters that read AC signals can be calibrated or implemented to read

average, root mean square, peak, or any other parameter desired by the meter designer., In the case of voice signals, there is a special meter weighting that indicates in VU - voice units. VU represents a special but standardized worldwide meter weighting so that it reads a sort of average voice power. AC signals, including voice, can also be measured by a digital meter. In the case of digitized AC signals, however, several samples must be taken and then processed mathematically to get an indication equivalent to the mechanical meter. The integration processing is done by inertia in the mechanical meter and electronically by the digitized meter.

The above paragraphs are not profound but are intended to clarify a confusion among a number of communication managers and technicians. That confusion is evidenced by the frequently voiced observation that ATEC is designed as an analog measurement device and so is not suitable for the so-called digital environment. As was pointed out earlier, the ATEC computer was designed for the digital world and has most of its relatives still working in fully digital applications using digital inputs from the controlled machinery. When the ATEC computer was inserted in the AC signal world, special samplers converting AC to digital format had to be provided along with some DC to digital signal samplers. No one thought that strange! The computer was programmed independently to process the sequence of AC or DC digitized samples to give the appropriate output reading. In the so-called digital world where the voice and data terminals are digitally coded and multiplexed to form a high speed pulsating DC or square wave AC signal, the communication manager and technician believes he sees a whole new world. In fact he refers to the square wave AC signal not

in hertz, but in bits per second. He sees no AC signal but only a 'digital' bit stream, yet the signal is identical with a highly limited or clipped analog sine wave. These people who confuse AC and digital signals are not really addressing technical basics, rather they are thinking in terms of the technologies that are routinely or normally used to process each class of signal. Those who have worked on FM radios will recall that the normal discriminator works from the highly limited 70M IF signal -- a 70 megabit signal is processed by the receiver. Yet this is recognized as an analog radio. In one Air Traffic Control radar the analog discriminator was replaced with a high speed analog-to-digital converter and fed directly to a digital computer for processing. The 70 MHz signal was the same in both cases, only the converter changed. Thus, from a basic technology standpoint, once the decision has been made to process the data in a digital computer, the only remaining question is how to sense the appropriate parameters needed to assess and control the process. In the case of communications systems this general question is independent of FDM-FM, or TDM-FM structure.

ATEC presently has AC and DC-to-digital converters that sample the signals of interest and provide a digital signal to the computer. In the 'digital' world the AC, DC, and clipped AC signals will be sampled and converted to digital format for provision to the computer. These sensors in the case of AC and DC signals can be identical with those now used. For clipped AC or bit streams pure sampling techniques may not be acceptable or may not be sufficient. In some cases, a simple integrator may be all that is needed and the output signal would be DC or varying DC or AC. Other

standard electronic sensing techniques may also be employed with the only point of constraint that the output be in digital format usable by the computer.

The issue then is not how does ATEC or SYPAC handle the 'digital DCS'. That is a trivial question. The real question is what parameters should be measured, or what measurements assess the real performance of the 'digital structure'. The proponents of 'going digital' have approached the problem much like the commercial world does. They install equipment, and since it is digital they believe it will not fail often because solid state integrated circuits are reliable. Yet digital equipment fails just about as often as similar vintage and quality analog devices. The customer service does remain 'like new' until failure or degradation below the operational threshold and consequently the customers service will be stable until failure, and may give the allusion of less failure. From the customer standpoint, this may be an advantage since he never gets noisy performance except just prior to full failure. From the O&M agency standpoint this actually makes the problem harder. No longer is noise a precursor and measure of degradation. Failures come abruptly and with no time to arrange for replacement or repair. It is not easy after a box has degraded to simply replace the bad one with a good box. In a structure spread world-wide, the number of boxes serially disposed is very large. If the box failure is complete and absolute, the identification may not be too difficult. But many failures are intermittent, temperature sensitve, shock induced, adjustment sensitive or as an interaction with other real life conditions. The Bell telephone company buys high quality equipment,

as does the British Post Office, and yet these people expect 2 to 3 outages per year on a 30 hop buried path that extends only a few miles. The DOD buys from the lowest bidder and intends to spread its system over 12,000 miles. Finding the degraded box or problem will not always be easy under these conditions.

Figure 8-1 is well known to all personnel who are familiar with communication theory. The figure shows the several key features that must be understood if true system performance is to be achieved and if proper design criteria are to be observed. Performance is plotted on the vertical axis, and degradation is plotted on the horizontal axis. The figure shows that a digital structure gives 'good' performance at conditions of no degradation, as indicated at point 'A'. At point 'B', the PCM structure still gives 'good' performance even though the degradation is approximating 25 db. Even at point 'C' where the deterioration is about 35 db, the performance has shown barely perceptable degradation, but it still 'good'. At point 'D' there is no performance at all and the degradation has changed performance from good to none at all.

The FDM performance is quite different. At point 'A' the performance is excellent. At point 'B' the FDM performance has fallen 25 db and is just good. At point 'C' the performance is quite degraded. At point 'D' the performance is only slightly worse than point 'C', but is still operational for some non-demanding services, such as teletype and voice.

This introduction was not intended to highlight the relative merits of FDM vs PCM or other digital form but rather to focus attention on a major point routinely missed by personnel not familiar with the practical facts

PERFORMANCE VS DETERIORATION FDM AND PDM

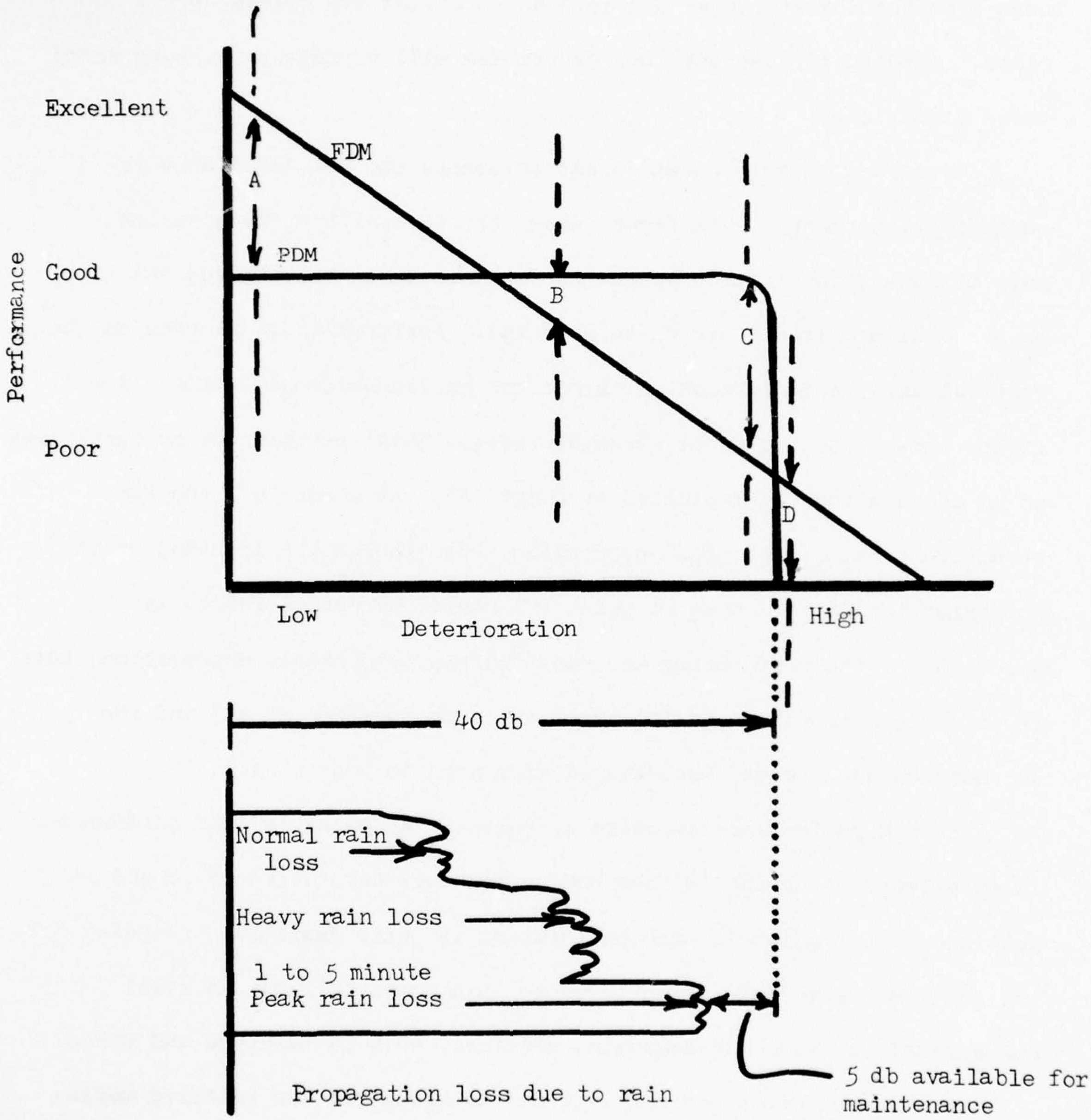


Fig. 8-1

of life of all electronic devices -- and specifically including all digital assemblies. All electronic components have a drift with time. Sometimes it is slow, other times it is faster, and depends upon: the particular electronic assembly; operating temperature as it appears in practice (and often not as the designer thought it would be); quality of the material; quality control during assembly; the basic design and safety margins used, and other factors. As resistors change value the solid state devices shift operating point, as capacitors change or develop slight leakage, further operating point changes occur and signal levels change, power supply ripple may increase a bit, or the sampling time may move slightly. The operating point on Figure 8-1 will have moved from point 'A' towards point 'B'. This operating point shift can be verified by an out of service loopback where calibrated stress is applied. This drift in the digital world will be entirely unobservable to the subscriber and unfortunately will also be unknown to the operator and maintainer of the hardware unless he has built in self assessment and stressing.

There is also another class of problems inherent with all digital devices, and the degradations so associated are cumulative with the above described componentry deterioration and lower the performance. When a pulse is generated in any device it is supposedly approximately square, although in reality it is distorted. This distortion is further aggravated by impedance mismatches and fortuitous circuit capacitance and inductance. The distortion sum is always significant, and always enough to move a normal 'A' operating point toward 'B'. For example, in a large computer of some

renown, a check of the bit stream at an interface point between the central processor and a drum memory, disclosed that the supposed square shape was highly distorted. The cable impedance mismatch was so severe that there was a repetition of the leading edge ring, appearing right in the center of the pulse. The center of the pulse was where the timing was placed for sampling. The ringing return echo was so severe that at a point slightly later than center timing, the pulse signal actually fell below half value and sampling at that point gave false readings. When the timing was absolutely centered the computer could be made to sample correctly, but any slighted jitter would cause it to make an error. In this case the operating portion of the computer was nearly at 'C' all the time. This same computer was installed with several central processors. The clock was connected to these processors with equal length cables. The closest processor had the cable coiled to neatly dispose the excess cable. There were prime power shielded cables in the vicinity. During some power maintenance an engineer touched the shield of the power cable with his hand, reaching through the coiled timing cable. The central processor failed. This test was rerun several times, because 'all' the computer people knew that no digital device was this sensitive. The change in inductive pickup of the coiled cable was tiny, but the slight increase in 60 cycle pickup moved this computer operating point from 'C' to D -- and it quit. Even a slight additional hum made the computer go non-operational. There was little performance degradation margin at all and this computer was erratically and unexplainably out of service. These examples are not unusual, the author's handheld calculator one day made repeated

errors when used for calculations while being charged. Some power line glitch was disturbing the bit shape. The reason for these examples and this discussion is to show that digital boxes degrade, or can be degraded, which is the same thing as far as the maintainer is concerned. The margin between point 'A' and 'C' is reduced and part of the performance design degradation margin presumed to exist is lost.

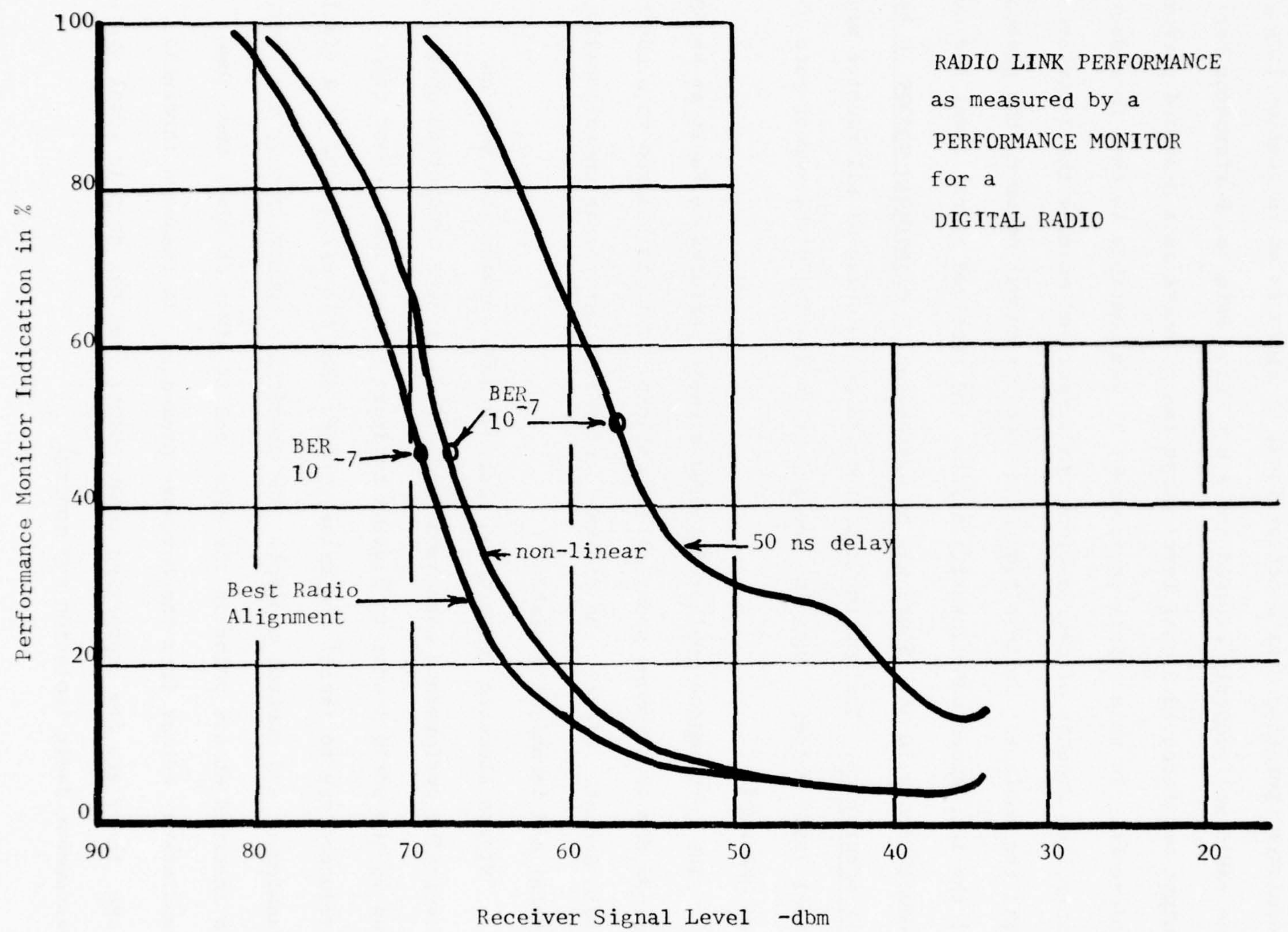
This practical phenomena can be examined as applied to the backbone structure. A design performance degradation margin of about 40 db is usually on a radio link. If the digital structure associated with the link is permitted to degrade 15 db and this is not an unusual amount for any radio, there is no measureable bit error rate increase as far as the customer or the maintainer is concerned. However, as a rain storm moves through the propagation path, the deterioration due to the rain is routinely 10-15 db at 8 GHz. The above link would still play but would retain no performance margin. There are rain storms however that have propagation losses 25 to 30 db, and on occasions exceed 35 db, for several minutes. The link would fail, the operator would undoubtedly report the outage as 'propagation'. The real reason of course in this example should be poor maintenance. Present day digital equipment gives the maintainer no way to test or assess his equipment except out of service.

It is clear by examination of Figure 8-1 that if 35 db rain losses can be expected on occasions, and if the link has been properly designed to the standard 40 db fade margin, that 5 db degradation is all that can be permitted on the digital hardware. This is a reasonable number, and is the same deterioration margin now used in the field for FDM.

The preceding portion of the study is not intended to dissuade anyone from digitizing but to emphasize that no system control mechanism can be expected to control a digitized structure unless some handles are put on it - handles in the form of parameters or measurements that reflect status and assess the performance of the structure, and mechanisms provided to accept corrective controls.

An idea was first proposed by the author and reduced to practice by Mr. Brandenstein, of the National Security Agency, whereby for the first time a measure of predictability was achieved in digital radio link failure assessment as is now accomplised in the FDM structure. This first test gave only 15 db in equivalent RSL prediction but was still enough to prove a point. The technique was a version of a stress test as described in the terminal section. In the radio test, the timing was offset artifically to create a condition where noise could more easily disturb the signal sampling -- an intentional movement of the equipment operating point toward 'C'. A later test offset the threshold voltage that demarks a one from a zero. The same bit error rate performance condition could be matched by a properly timed signal detector but with the received signal level -- RSL -- reduced by 15 db. Later developments by the AFCS digital test bed and by the Raytheon Company gave results of 30 to 35 db equivalent RSL prediction. This is a salutory accomplishment, since in 1971 most people said that it could not be done.

Figure 8-2 displays some early work done with one version of the digital performance assessment monitor. The monitor in this



RADIO LINK PERFORMANCE
as measured by a
PERFORMANCE MONITOR
for a
DIGITAL RADIO
Performance Monitor Indication in %
100
80
60
40
20
0
90
80
70
60
50
40
30
20
Receiver Signal Level -dbm
BER 10^{-7}
BER 10^{-7}
non-linear
50 ns delay
Best Radio Alignment

Fig. 8-2

case was applied to a digital radio -- a three level partial response modulator operating over a conventional FM radio in an in-station loop. The radio was properly aligned and a Bit Error Rate vs. Performance Monitor Output vs. Received Signal Level curve run to serve as a standard performance reference. In this stable environment it was possible to then introduce controlled amounts of degradations and stress and measure the deterioration with the monitor. In this figure the monitor output detected the presence of the introduced non-linearities after the received signal level had been reduced about 10 db. <u>There was no operationally measurable change in the bit error rate</u>. The monitor detected the phase delay at all receive signal level (RSL) values. Again no operationally meaningful bit-error-rate change was observed.

The performance monitor detected a radio performance fault at an RSL of -35 dbm or stronger under all conditions. This is related to a basic radio defect. Clearly the digital performance monitor is operationally useful and technically viable.

Nippon Electric Corporation also has done considerable work on meaningful performance assessment and offers it as a production option and is the world leader in digital hardware at this time. Most other producers try to 'sell' the false premise that bit error rate is a viable management and control concept. The predictive sensor is only one step. It is inserted at one point in the site, and it gives an alert when some cumulative effect from the hardware preceding it passes a threshold. To date, there are few supporting measurements that can help in total system assessment fault isolation and control.

The author has identified nearly 20 other parameters that may be useful in assessing the performance, and expanding the understanding of the true status of a digital structure, as the basic performance assessment step, in full system control and analysis.

In the FDM world more than 9 years work found that 8 parameters were good and sufficient parameters to assess the FM-FDM backbone structure. There are a limited set of additional parameters needed to ascertain the performance of each network. The TDM world in general has not yet even recognized the need for performance assessment, and little in the way of effort is underway to even investigate the problem. The near term DCS probably will be a "low bid" average quality commercial structure that will struggle to give commercial likelihood of communications of approximately 95% and with little in the way of assessment and control.

There is a large group of people, most of whom have received their education since the emergence of the computer as the problem solving utopia. These people believe that digital technology is completely new, and that none of the ills of the FDM electronic world pertain. They think that digital devices somehow will never fail except due to very isolated component breakdown because of manufacturing defects, and see the long life expectancy of digital devices as resulting only from the digital nature of the equipment. This, of course, is false. The longer life is due to the solid state active devices and new manufacturing technology. Anyone who has a bit longer experience will recall the less then wonderful results obtained by the digital Semiautomatic Ground Environment -- SAGE -- large

digital computer implemented with the highest grade tube technology available, for Air Defense use in the late 1950's and early 1960's. Digital technology is little more reliable than the same vintage and quality analog hardware. The unlimited optimism evidenced by these people is without basis.

There are only a few people who are at home in both technologies and who recognize that digital signals are just highly limited (clipped) analog signals, and most digital signals are in fact generated analog the clock for example. The digital devices do not attempt to determine the actual amplitude value of the signal, but merely ascertain the presence or absence of a signal. These few broadly experienced personnel know that digital technology is both different, yet much the same. Some of the assessment techniques developed for the FDM world will apply in the new digital era -- receive signal level and delay distortion are two examples. Some elements of the digital world have no analog equivalent, such as quantizing noise in encoders. In most cases, however, the function remains, but a one for one correspondence between the two structures does not exist. Idle channel noise can be measured in both the FDM and digital world but the readings do not convey comparable information.

Idle channel noise sampled in the FDM world gives an in-service Noise Power Ratio evaluation. Idle channel noise in a digital structure may portray low frequency quantizing noise, low receive signal level, or noisy input cabling to the TDM Multiplex. Clearly the measurement is the same, but equally obviously the associated symptoms are quite different, and the analysis required to isolate the difficulty is changed.

Of even more interest is the change in instrumentation needs. This sensitivity to instrumentation is well illustrated by comparing several measurements made by ATEC to observe drop outs on some circuits of interest. The drop out measurements made with a 2 millisecond period showed no losses of signal -- there were no drop outs. The ATEC remeasurement using 1 ms however showed 700 to 1000 drop outs in an hour period. One millisecond voice dropouts are not noticeable, but the same length dropout on a digital channel will cause the loss of 64 bits, quite a different matter. These dropouts were traced to dirty patch jacks, exactly the sort of jacks being installed in the digital structure -- because they are cheap.

In the FDM world the key parameters assessing system performance are known, but more importantly the interrelationship among these assessment parameters is understood. In the digital world there are few indicators that are correlative with each other or with the predictive sensor described previously.

The sensors that the commercial world uses to control their structures are nearly restricted to the clear failure mode identifiers. When the multiplex loses synchronization, when there is loss of bit integrity in the bit stream as the customer sees it, when the bit error rate goes up, or when the receive signal level drops, all these failure indications are alarmed. The alarms may also be wired to switch equipment stacks, if associated with a radio, or a multiplex, etc. All this minimizes the outage, but an outage there is. It may be short, it may be extended, but in any case, except the RSL induced radio stack transfer, bit integrity

is lost, but then the commercial world only attempts to provide 95% overall service. The Air Force and DOD cannot expect to use the lower grade commercial hardware, and these same 'alarm only' failure alerts, and achieve 99.99% service worldwide. No rhetoric, however impassioned or honestly thought,can change these facts.

There is much work yet to be done on hardware, box, assembly, site and link performance assessment before the service reliability of a digital structure can, over an extended time period, match that of a well-run FDM-FM structure properly sensed and managed.

For obvious reasons the Air Force and DOD are going digital, but many actions will have to be completed prior to achievement of real and effective system control. The matter will be much more difficult if addressed by later control overlay. No tech control development can substitute for lack of a properly sensed structure. The entire system design must start from the digital hardware implementation and build up to interface through suitable sensors to SYPAC. DOD will have to face the facts of life, and recognize that off-the-shelf hardware, unmodified, is unsuited to worldwide needs. Some form of applique must be added to all commercial gear if the fully assembled structure is to meet requirements. Failing this, properly designed hardware will have to be developed and procured by the military.

IX. ATEC PROOF OF THE SYPAC CONCEPT

Throughout this study the term SYPAC has been used to describe the total future System concept, including the backbone structure, and the networks. These two major elements integrated to form the worldwide communication system. Included are all the assembly of equipment, hardware, and devices on air bases or other places where subscribers enter and exit the communication fabric.

A. Summary

ATEC has also been referenced numerous places in the study. The term ATEC is the DOD acronym for the hardware developed generally to the SATEC concept and now in field test in Europe. ATEC measurements refer to the actual assessment and printout capability as presently provided by the hardware.

ATEC is in theory, and also in real life practice, the first partial implementation of SYPAC. The key to this success in meeting operational needs 10 years after the concept was published is because the ATEC concept was designed with the minimum hardware implementation. The bulk of the sensing performance assessment and analysis was accomplished by a digital computer by software. This approach was selected because a computer can be replaced by another with faster processing speed, or bigger memory, in a centralized or decentralized configuration. Of course, the program can be modified, converted, expanded, or new elements can be added with ease.

The computer heart of ATEC has been formulated and reduced to practice. There are many who view ATEC as an automation only of those activities which

are currently accomplished in tech control, and the testing by the development agency focused only on this area. This is a completely myopic and non-systems oriented view, although ATEC certainly automated some of these functions. The goal is not now and has never been aimed at the automation of tech control functions.

B. Background

The original concept of ATEC was born in 1966 and published in 1967. The concept study portrayed for the Air Force and DOD, the basic structure of ATEC, under the original acronym, SATEC, Semi-Automated Tech Control. There were a number of system factors covered in this report. The basic structure for ATEC, covered mission management, although in some respects, dimly. It was evident even in 1967 that the first and foremost problems constraining the activities of this Command was the lack of ability to keep the communications backbone structure operating at a satisfactory level.

Networks of all types were having difficulty. Each, of course, failed at a different time and for different reasons. It was not generally understood at that time that a teletype network should, if properly maintained, fail after voice nets were unusable; that voice should be useful even though low-speed data nets were troubled, and that high-speed data networks fail before all of the others.

The above is always true when noise is the primary cause. It is technically possible that some voice circuits might work well even though teletype has quit if frequency offset within the backbone structure is the key problem and is severe. Since much equipment maintenance and operation is is poor, obviously other failure modes are evident. But even in 1967, it

was evident that the first step in understanding and managing a total communication system with its wide flung networks, must come as a result of stabilizing at an acceptable level all the elements common to the networks, including the backbone structure. As such, the first meaningful step in this direction resulted in SCOPE CREEK and its resultant identification of the myriad of problems requiring solution. SCOPE CREEK and previous assessments and field tests by the author provided the full realization of a workable backbone sub-system concept and permitted fleshing out the basic structure outlined by the SATEC report in 1967. The backbone problems, being the first and a basic step toward system improvement was emphasized.

Under the joint 3-service-DCS umbrella, ATEC hardware developed into a highly flexible device composed of parameter converter and a digital computer, and configured to sense and process parameters in an automated manner and present information on the status of the backbone structure and also network elements within the communications system. It was intended that ATEC interchange working data laterally to facilities of equivalent responsibilities on common problems and to provide status information vertically for use in the management structure.

C. ATEC System Capabilities

Starting in 1973, the testing of ATEC in the field changed as far as AFCS was concerned from the box by box approach pursued as required under the development contract, to the system oriented testing predominantly conducted by the HQ AFCS and by the Croughton Comm Group in England. Thin line system tests have been run that covered much more than the backbone

structure. The testing was conducted at Croughton. Certain tests required the electrical but not physical displacement of the ATEC sensing from Croughton to Hillington. The fact that this could be done easily demonstrated one of the first capabilities not recognized by those who ran the ATEC box hardware acceptance test and by those who viewed ATEC as tech control oriented.

1. Backbone Structure

The tests at Croughton proved that the ATEC was able to make measurements on single links. It demonstrated the capability to test through a number of links to adjacent major nodes, and through these major nodes to points, and other major nodes far removed throughout the backbone structure. Specifically, ATEC was able to detect faults in the structure at Mt. Virgine, Italy, Coltano, Italy, and Feldberg and Langerkopf, Germany, etc. The parameters included not only the idle channel noise measurements, but level stability, noise characteristics, power line hum present, tones within the channels, frequency off-set, harmonic distortion, etc. All of these measurements were done "in-service" with no disturbance to any customer and with no cooperation effort, or, in fact, knowledge of any remote site. ATEC was delivered with 29 parameters measurable. The R&D tests used, in a practical sense, 9 of them, AFCS operational tests used 20 and has demonstrated need for at least 30 more.

Heretofore, to perform quality control measurements or perform the Link Assessment Program, personnel and test equipment were required on both ends of the path at the same time and the circuits had to be removed from customer service. ATEC proved that such practices need not continue. ATEC

demonstrated that measurements can be made as required in-service with no collaborative effort at the other end even during peak traffic load periods.

While at Croughton, the ATEC accessed the tail circuits connected to this tech control. The tail links were evaluated with generally the same techniques as that used in the backbone structure, and it worked with equal facility and accuracy. ATEC also evaluated tail circuits that did not enter the tech control at Croughton but connected to tech controls 6 to 10 radio hops removed including Bentwaters and Weathersfield AFBs. This is important from an area responsibility standpoint and disproves the uninformed view held by some, that ATEC is a tech control oriented concept.

At the termination of the testing of the tail paths, the cable circuits on all bases whether local or all the way across England were assessed to the manual PBX and later to selected customers within the base plant. Manual interconnections were used on base, to access the needed circuitry. It was straightforward to measure the idle channel noise and other selected parameters that indicated the condition of the base cable plant. There are simple techniques for automating both the measurements and the interconnections for repetition monthly or on whatever time sequency seems appropriate.

These few but basic brief tests have made it clear that ATEC can measure the backbone structure, the tails, and the base structure -- thus end-to-end, user-to-user circuit assessment capability was demonstrated. Obviously, there are practical constraints that limit the size of the

geographical area that can be so performance assessed, but the stage has been set for area backbone structure management. The practical constraints on the size of the area, the software composition to portray to each level of management only that data needed for effective action, and other similar matters are among the key issues yet to be fully evaluated.

The evaluation of ATEC to date has been on an FDM-FM and audio structure and with digital traffic introduced by modems. At some future time, the structure will become a mix of analog and digital. The functions of ATEC will not change in the least, even when the full digital world arrives. ATEC presently has analog to digital converters as sensors to present the measurement data to the computer in an appropriate digital form to manipulate. In the future, ATEC will need to add only digital to digital converters, or digital to analog converters (as presently accomplished by the AFCS sensor at the AF Digital Systems Network Facility). The added sensors or suitable performance indicators can be an integral part of the basic digital equipment, or may be an applique added to the structure, but in any case represents a trivial cost once the proper parameters to assess are ascertained, and only the ATEC software need be changed to meet the needs of the future.

2. Networks

The networks of the DCS have terminals, processing devices, conditioning equipment, and switches, and all this hardware has its fair share of operations, maintenance, and management difficulties.

SYPAC, in its role of mission system control, must obviously assess the

performance of the networks and provide the data from which proper network decisions can be made. During the recent ATEC network tests, many problems were detected with the Autodin network, the Autovon network, the weather dissemination network, and the one dedicated voice network tested. Again, these problems were detected in-service with no one else aware in the tech controls or management structure that there was a problems or that ATEC was able to make the assessment without some remote site cooperative assistance. The point of most interest, however, from a system assessment standpoint is the ease with which the ATEC was used to measure these network difficulties, in-service. There are many critical and salient signal signature parameters which have already been derived to sense in-service the network performance and to predict trouble with the network, and warn as certain failure thresholds of the networks are approached. Most of these network signal parameter assessments were made based upon the fast Fourier transform (FFT) or software manipulation -- clearly a highly flexible and operationally required capability. In the case of the Autodin network, several of these characteristic signal parameters have been ascertained that give useful and unambiguous indications of the health of the network. More are needed but the principle is established. Thirty to 50 such parameters may be required for use in the other major DCS and service network assessment.

In the case of Autovon, it is fortuitous and highly helpful (but not necessary) that all Autovon switches are collocated with major communication nodes. Further, these switches are interconnected by signaling tones of prescribed levels and unique characteristics. These unique characteristics were sensed by ATEC at the transmit end, and at the receive end, and several

points in the middle. These measurements include level, level stability, idle channel noise, signal to noise, phase jitter, and a number of other useful parameters conducted while the interswitch trunks were idle, and using no cooperative help from the remote end.

During the AFCS evaluation of the Autovon in-service assessment of the interswitch trunks in 1974, it was noted that periodically the ATEC fast Fourier transform derived idle channel noise, deviated from the normal figure. (ATEC and manual measurement agree closely.) The difficulty was not fully isolated in 1974 although the disturbance was immediately isolated from the FFT spectrum analysis as to source. The tones were those emanating from the Autovon switch. The cause of the tone leakage was not pursued because the ATEC solution was obvious. The ATEC fast Fourier transform had already noted and measured the spurious tones, so those few idle channel noise measurements with SF tones were discarded. Later analysis has found an SF unit design defect. Subsequent analysis, however, has disclosed that only about 17% of the measurements are disturbed by the SF defect. This is of little operational impact. Software instructions to ignore these tones could solve the problem quickly and at negligible cost. The SF unit need not even be corrected from a system assessment standpoint, although the author does not believe known defects should be permitted to exist if the correction is not expensive -- it is easy and cheap in the SF unit case.

Trunk usage, and type of traffic present and other in-service measurements were also made, such as voice level, dial tone level, and frequency, etc. Obviously, the sum of the idle switch channel assessment

plus the many channel parameters is sufficient to characterize the condition not only of each trunk but also by integrating the performance of the trunks in a link -- as done by the DCA PMP program -- assess the link performance as a by-product. Thus there was little need for a separate link assessment effort. The ATEC summarization of all interswitch trunks gave the condition of that portion of the switched network and the backbone structure.

It was similarly easy by examining the in-service signals of the weather facsimile network and find a bad transmitter. While in England, ATEC found a problem at Offutt AFB, Nebraska. It was found that the black/white ratio was incorrect (a transmitter problem) on a weather facsimile transmission, and also found that the signal level from the States to Europe was too high. The signals arriving in Europe were an order of magnitude too hot. These were network problems and unrelated to the backbone structure.

Parameters may but need not be synchronously sensed by the several transited ATEC controls, since any one can give positive identification of sensed problems to all the managers. Further, non-synchronous scanning provides more frequent assessment throughout the network. There are other indications of network difficulties or degradations which also can be detected in-service and can alarm the management structure of impending difficulties and necessity for corrective action.

D. SYPAC/ATEC Extraordinary Capability

A very important capability was validated during the system testing accomplished by the author and the personnel at Croughton in late 1973 and

early 1974. The impact of this concept is overriding and justifies reformulating all previous conventional system performance assessment, fault isolation, analysis, status presentation and control approaches. Many people believe that most problems are encountered in the transmission media, thus they conclude that prime attention must be directed at the wideband structure. They further conclude that the transmission media must then be afforded full attention, and they relegate system/network matters to a subordinate position, and frequently fail to consider them at all. This conventional but defective logic leads to a technically unsatisfactory, and cost prohibitive system control partial approach, that fails to address the total system and its real life user to user problems.

The ultimate end goal of SYPAC must be to raise total system performance to what ever level of optimization the DCS managers establish. Clearly then, the focus of management attention on the transmission media with tertiary interest in the customer networks is a very poor policy. Fortunately, the ATEC test results provide measured proof that the SYPAC system/network oriented approach is technically excellent, highly cost effective and in the final configuration cheaper than the alternate approaches.

Briefly, ATEC demonstrated the capability based upon the digital sampling and Fourier transform, to make a measurement, and then by software processes, derive any number of separate parameters. Many people have seen the conventional idle channel noise, signal level, etc., ATEC printouts. The ATEC is considerably over engineered if this is all that is required but much

more is needed. These simple noise and level measurements can be made with a conventional level meter. The sophisticated elegance of the ATEC approach permits the extraction of parameters of network/system interest from the measurement of network signals. The signal Fourier analysis and software permits recognition of the signature and thus identification of the terminal, switch, or other signal source. Thus the channel and network routing data base can be constantly validated. If a terminal is rerouted ATEC software can immediately recognize the change. It could, by suitable software, also report the previously unrecorded change to the management structure. After the signature is recognized, the standard signal degradation thresholds can be applied to ascertain whether Amber or Red thresholds are being approached. Selected measurement manipulations can be performed -- again by software -- to analyze the signal for normal or unusual distortions or other action to assure acceptable terminal, switch or signal source operation -- i.e. normal network functioning user to user.

As a by-product and derived by software already in the ATEC, the channel noise and a number of other channel parameters can be provided from the same signal sampled data used for network assessment. Thus channel and link status can easily be derived by software actions. This means that in many, perhaps most, network measurements there is no need for a separate channel and link assessment with the concomitant reduction in assessment scanning time, duplication of data, time correlation of channel/network problems, lack of agreement among measurements not time coincident, etc.

The ATEC hardware now gives measurements for which no processing algorithms are as yet derived. The software needed for most measurements is complete, but the system processing and analysis embodiment is not yet fully formulated. The uses of ATEC are very flexible but are generally understood by only a few personnel.

Much software work remains to be done, but the important and basic observation must certainly be that at this point, ATEC has failed no assessment test and has demonstrated highly flexible measuring capability. Notably it was able to provide suitable answers whenever the Air Force or DOD could pose an appropriate question.

The conclusion is that ATEC has proved that the SATEC approach is sound. It further has validated all of the major basic precepts and concepts of SYPAC, and opened the way for rapid transition to a fully optimized and controlled DCS and at minimum total system cost using the ATEC proved capabilities. The reporting potential offered by ATEC is much advanced over the present DCS and O&M command present reporting but the capability is not yet structured in the software program.

It is of utmost importance to recognize that all of the ATEC capabilities demonstrated in England and in Germany, and briefly discussed above are provided by a special signal sampler followed by a digital filter/processor. The salient capability is such that as the DCS matures, changes to any of these assessments, signal analyses, signature recognitions, degradation recognition and quantization, and any other analytical capability envisaged can be provided with:

a. no hardware cost

b. simple software changes

Of most cost impact, all of these capabilities can be available,

c. at completely unmanned sites with ATEC control and direction remoted to any convenient location for cost, management, customer service, or technical reasons.

X. SYPAC IMPLEMENTATION INTO THE DCS

A. Problem

Anyone who watched the operation around any communication structure is well aware that almost nothing is ever thrown away. The various boxes or assemblies are normally modified or rebuilt and the various sites and facilities often have quipment added or existing hardware overbuilt to provide added capacity. The action almost never taken is to discard a major element and replace it with completely new hardware. Even in the DEB, the radio is a modification of a conventional FM version, and the whole DEB will still retain FM type radios. Only the mux is replaced. The normal approach is to slowly mold the basic elements already in place to meet new requirements. What superficially seems like a relatively reasonable change, grows into a large logistic, maintenance, operation, and management task. The DSTE terminal implementation is a good example. The communication system is frequently disrupted unless the utmost precautions are taken.

It is logical to consider carefully the manner of accomplishment of all changes to the system. SYPAC obviously is no exception and it must be done well, but for different reasons. SYPAC is not serial with the structure so it will not disrupt the service. Rather, the care and sequence required in the introduction of SYPAC is to maximize the system assessment and control capability for the cost invested. This means that each step in the conversion must be well thought out, and efficiently and effectively implemented, complete with the requisite hardware, software, organizational

and management changes. This means that all facets of the implementation must be examined, including the production funding, the installation drawings, the installation and test, the operational training, the restructuring of the O&M organization, the reformulating of the reporting hierarchy, and the re-education of the O&M and DCA managers to respond to the SYPAC outputs. The creation of the assessment and control mechanism for the networks is completely dependent upon reflection of all of the above concepts into network switch and terminal hardware specifications, and the retrofit of existing hardware, with long expected operational life. to interface with SYPAC. The above necessary steps cannot be done quickly even from a purely technical standpoint. When the fiscal considerations are added the total time becomes quite extended. The organization and management inertia and learning and training periods further extend to the time cycle.

It will be necessary to spread the SYPAC implementation over perhaps 10 years, and it is quite likely with the pressures on the military budget, the full conversion period could take longer.

B. Implementation Approach and Sequence

1. The first major element of SYPAC to be installed must be of course that element of the total SYPAC structure that automates the performance assessment functions that must be performed in and around major switch tech control nodes. SYPAC will automate much of what is now being accomplished in tech control, but the tentacles of these measurements extend much beyond tech control. Much of the manual activity and the manipulation now

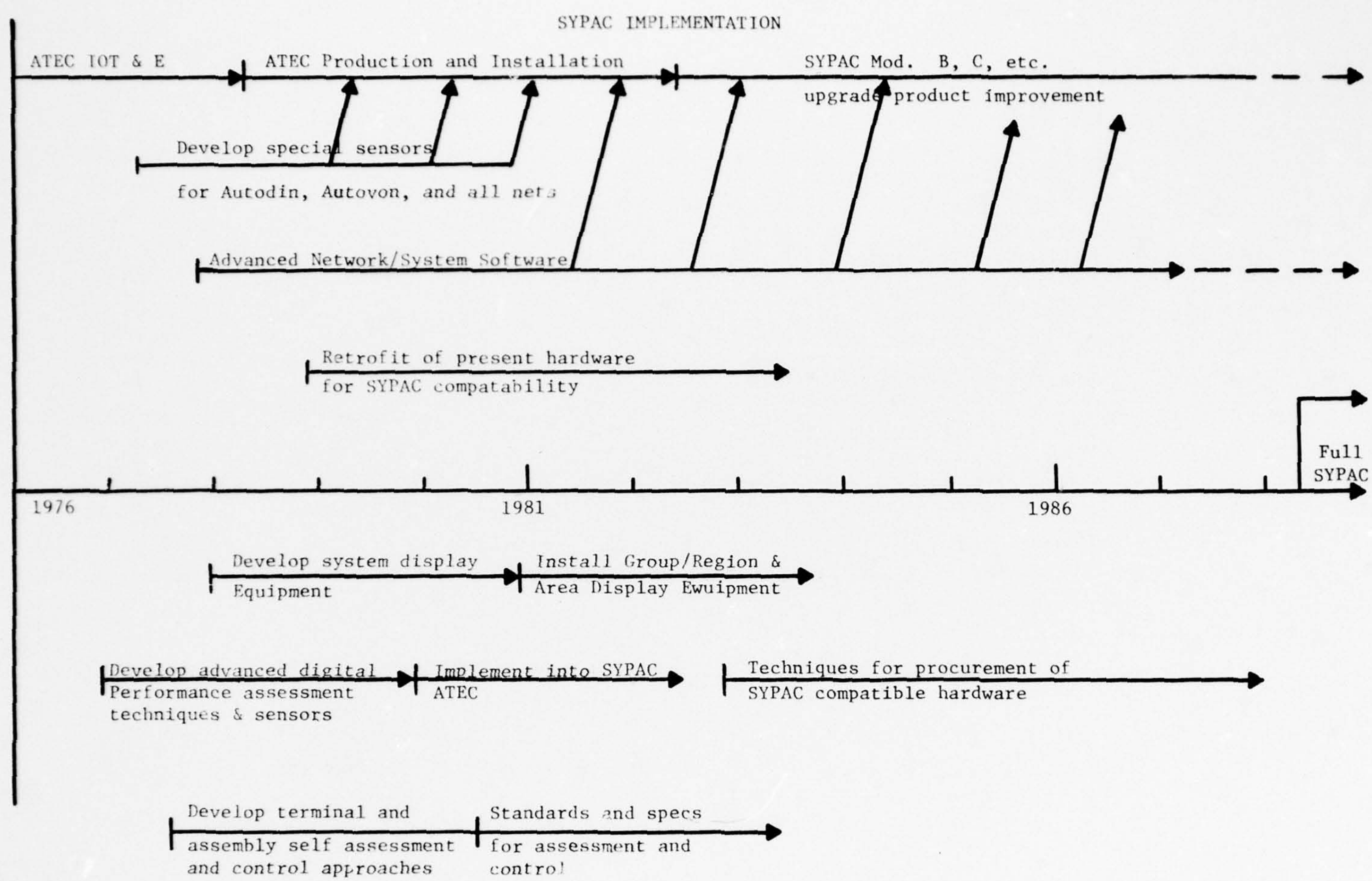
widespread need not be done in any well ordered and instrumented communications environment. To emphasize -- SYPAC does not primarily just automate tech control. It does automate those measurements that must be made to assess and control the networks and derives the backbone structure status as a subordinate corollary and this is accomplished at major nodes, that is major RF link hubs collocated with switch sites. It is far more important from both the O&M and DCA standpoint to install SYPAC at all switch/major nodes in Europe, for example, than to saturate that area, concentrating on measurements of the radio sites and links. Obviously concomitantly with the first major node SYPAC installation must be the construction of a viable orderwire structure to replace the present poorly implemented orderwire structure, among the major nodes.

2. The second major step in SYPAC implementation will be the installation of the Region (Sector) Facility Control Subsystem. This is the SYPAC element that integrates the activities of an entire region. It is the lowest element that can address system factors, and network matters in an effective manner. The orderwire structure must be expanded both laterally among Sector Controls and vertically up and down to incorporate the added interchanges.

3. The third major phase is the tie together of all Region/Sector elements to the Area -- both O&M and DCA. This step may not require a SATEC hardware element, but may be satisfied by interconnection to one of the existing DCA or O&M computers directly, or through an interfacing processor.

4. The fourth step is to fill in the voids between the major switch tech control nodes to provide hardware monitoring and additional fault isolation information for the O&M agencies, but only where the capability described in Chapter IX D must be supplemented. This fourth step clearly provides the least return on the investment from a system performance and control standpoint. Added SYPAC sensors to permit unmanned sites are more cost effective, and in those cases may be elevated some in priority. Many of the newer radios and multiplex have structures that remote the alarm parameters, and provide remote control and equipment switching. The fact that a radio failure triggers several alarms indicative of the same fault is not a matter of concern to field personnel. Clearly the fourth step is the least cost-effective phase. The first and second priorities however are far and away the most important steps in the first few SYPAC years.

The SYPAC final software will require a long time to develop fully. The full complement of sensing, manipulating, analyzing, reporting, etc., concepts will be an evolutionary procedure. Further, SYPAC software will have to be time phased with the four above steps and with the plant-in-place hardware modernization and modification to meet the military operational needs.



SYPAC IMPLEMENTATION
ATEC IOT & E
ATEC Production and Installation
SYPAC Mod. B, C, etc.
upgrade product improvement
Develop special sensors
for Autodin, Autovon, and all nets
Advanced Network/System Software
Retrofit of present hardware
for SYPAC compatability
Full SYPAC
1976
1981
1986
Develop system display
Equipment
Install Group/Region &
Area Display Ewuipment
Develop advanced digital
Performance assessment
techniques & sensors
Implement into SYPAC
ATEC
Techniques for procurement of
SYPAC compatible hardware
Develop terminal and
assembly self assessment
and control approaches
Standards and specs
for assessment and
control

Fig. 10 - 1

MISSION

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RADC plans and conducts research, exploratory and advanced development programs in command, control, and communications (C^3) activities, and in the C^3 areas of information sciences and intelligence. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.

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